BOSTON UNIVERSITY
COLLEGE OF LIBERAL ARTS
LIBRARY

THE AMERICAN
JOURNAL OF PSYCHOLOGY
Founded by G. Stanley Hall in 1887

Vol. XXVII OCTOBER, 1916 No. 4

THE MEASUREMENT OF ATTENTION IN THE FIELD OF CUTANEOUS SENSATION[1]

By K. M. Dallenbach, Cornell University

We have recently published a study in the measurement of attention within the field of audition.[2] Since that time we have repeated the work within the field of cutaneous sensation, and it is our purpose in this paper to present these additional and confirmatory results. We do not intend at this time to criticise the methods of dealing with the problem of attention, or to draw theoretical conclusions from our results. At some later date we hope to deal comprehensively with the facts, the methods, and the criticisms of the measurement of attention; but we have wished not to delay unduly the publication of these results.

Methodically, the present study differs in no important respect from its predecessor, except that cutaneous sensation is substituted for auditory, and that the attributive changes are therefore changes of intensity and extent instead of changes of intensity and pitch. For general procedure and details of method the reader is referred to the earlier paper. In general our tables can be understood from the description there given, if substitution of extent for pitch be made. It would be well, then, if the present paper were read with the other at hand.

[1] Presented at the Chicago meeting of the American Psychological Association, December, 1915. The experimental work was done in the psychological laboratory of the University of Oregon in 1913-15.

[2] K. M. Dallenbach, this Journal, XXIV, 1913, 465-507. L. R. Geissler, *ibid.* XX, 1909, 502-529, first used the method for vision.

Observers.—The observers were Mr. E. Good (G), Miss G. Cross (C), and Mr. M. Goodwin (Gn). All three were advanced students in psychology, and had had considerable practice and experience in introspection. They all worked without knowledge of the problem, and they served regularly three hours a week.

METHODS

Preliminary Training in Introspection.—The procedure was practically the same as in the earlier work,[3] except that the interval was shortened (30 to 60 secs.).

Practice was continued for four months. At the end of the third month the scale of degrees of clearness[4] had been worked out by all observers.

Preliminary Practice in Observation under the Normal Conditions of the Main Experiments.—Our stimulus was a faradic current from a Harvard inductorium. Four large Edison-Lalande cells (E. M. F. 0.85), arranged in series, were used to actuate the primary coil. The strength of the primary current was practically constant, for at the beginning of every experimental hour we reduced the current, by the aid of a small rheostat, to 25 amperes. Measurement was made by a small ammeter shunted into the circuit. There was a slight reduction in the current as the hour and the experimental work progressed; but since only 4-6 experiments were conducted during the hour, and since an experiment lasted only 20 seconds, the reduction was very slight and the current might be regarded as constant. In any case, as Martin[5] has shown, a slight variation in the strength of the primary current will cause no appreciable change in the strength of the secondary.

The intensity of the secondary current was controlled by a shift in the position of the secondary coil. The extensity of the stimulation was controlled by a three-way switch which permitted us to shunt the current to any one of three electrodes which served as stimulus.

The common electrode was placed at the back of the neck over the *vertebra prominens* and the other, the stimulus (three concentric copper rings) upon the dorsal side of the left forearm about 10 cm. below the elbow joint. The areas stimulated by the three electrodes were all supraliminally different. This was determined empirically and separately for each observer, and a value was taken which was well above the limens as follows: the area of the smallest electrode was 7.06 sq. mm.; that of the medium, 94.25 sq. mm.; and that of the largest, 188.69 sq. mm. The smallest electrode was round, 3 mm. in diameter; the medium was a ring 2 mm. in width, with an inside diameter of 13 mm.; the largest was likewise a ring 2 mm. in width, with an inside diameter of 28 mm. The medium was insulated from the other two by sealing wax. The cutaneous sensations were localized at the arm. At high intensities the current was also perceived at the neck: a limit which, once determined, we never approached. Owing to the difference in areas stimulated, and consequently in the amount of resistance offered to the current, the sensations from the three electrodes were not of the same intensity. Therefore resistance was added to these circuits such that the intensity of the cutaneous sensations was equal for equal intensities of the current. The amount of resistance to be added was

[3] Pp. 467f. [4] P. 468.

[5] E. G. Martin, *Am. J. of Physiology*, XXII, 1908, 61-74; 116-132.

different for every observer, and individual rheostats were accordingly provided.[6]

The changes in the intensity of the cutaneous sensations were also supraliminally different, extending in every case through two just noticeable differences. These steps were computed separately for every observer by the method of Just Noticeable Differences.

The three-way switch, by which the current was shifted to the different arm-poles, and the secondary coil of the inductorium were fitted with large scales and long moving arms, which permitted us to make gross movements in their adjustment.

The observer's left arm and hand, dorsal side up, were secured in a plaster cast which prohibited all movement, whether voluntary or involuntary.[7] The electrode was held in position, 10 cm. below the elbow joint, by an elastic band, which insured not only that the electrode would be returned to the same area from experiment to experiment, but also that it would be held on the arm at a constant pressure.

The pressure, including the weight of the electrode, was 200 grams for G; 196 for C; and 199 for Gn. The area stimulated was frequently shaved, and before every experiment was bathed in a concentrated salt solution.

The electrode at the *vertebra prominens* was composed of a nickel-plated brass plate 3 cm. by 6 cm. It was covered by a felt pad 1 cm. in thickness. This pad was thoroughly saturated at the beginning of every hour with a concentrated solution of salt. This electrode was secured in position by an elastic tape encircling the neck.

The observer was seated at a table in a dark room with his left arm secured in the manner just mentioned, and his right hand resting upon a silent electrical key; and the experimenter was placed with the induction coil and the control apparatus in a room near by. The observer was, moreover, enclosed in a muslin booth, illuminated from above by an electric light controlled from the experimenter's desk. The experiments were conducted in dark-adaptation, and the light was turned on at the end of an experiment so that the observer could write his introspection and bathe his arm, while the experimenter was preparing the apparatus for the next experiment.

The graphic records of times were obtained in the same manner as in the earlier experiment.[8]

The *instructions* were those of the previous experiment, adapted for the altered conditions.[9]

The time of an experiment was decreased to 20 secs. in order to increase the accuracy of report.

---

[6] My thanks are due to Prof. Wm. P. Boynton, of the department of physics at the University of Oregon, who aided me in standardizing my apparatus, and who suggested the lead-pencil rheostats that were used to equalize the intensity of the cutaneous sensations; and to Mr. Wm. H. Kiler, of the engineering department of the Southern Pacific Railroad, who aided me in constructing and setting up the apparatus.

[7] We at first attempted to work with the volar side of the arm, but soon abandoned it for the dorsal side. The change was imperative because of the great number of motor centers on the volar side. We found that it was impossible to stimulate any area upon this side of the arm, within the necessary limits of our experiment, without causing some muscular contraction. This distraction was eliminated by shifting the electrode to the other surface.

[8] P. 469. [9] P. 469.

The detailed *arrangement of series* followed the general principles laid down in our first paper.[10] There were 76 series in all. These involved 104 changes of extensity and 104 changes of intensity. Half of each were changes in the direction of greater, and half in the direction of smaller.

In this practice work G performed 40 experiments; C, 68; and Gn, 58. The work covered a period of three months: April, May, part of October, and part of November, 1914.

Single Task Method.

Six distractors were employed:

1. Flicker (8 rhythms and 10 intensities).
2. Buzzer (3 intensities).
3. Electric bell (3 intensities).
4. Metronome (4 rates: 60, 90, 120, and 150).
5. Flicker and metronome (with above variations).
6. Phonograph.

The flicker was produced by means of the electric bulb which was used to light the booth in which the observer worked. The illuminating current was made and broken very rapidly by a device connected with a small motor. Ten variations of intensity from very weak to the full intensity of the light were given by a rheostat. Eight cadences were used, which varied from regular, slow, and rapid, to discontinuous and jerky.[11]

Different intensities of buzzer and bell were obtained by varying the strength of the current.

The phonograph stood upon the experimenter's desk; the sound was conveyed to the observer by a speaking tube.

Instructions and *series* were practically identical with those for the Single Task Method in the earlier experiment,[12] except for the changed conditions and the reduction of the period to 20 secs.

Every observer performed 76 experiments under this method, all during the winter of 1915.

As in our other experiments,[13] only the higher degrees of attention occurred. Hence it was necessary to supplement the results by those of the Double Task Method.

Double Task Method.

The second task was that of continuous addition or subtraction. The procedure was in general that of the earlier paper.[14] Three 'difficulties' were used, and the numbers were so chosen as to give greater uniformity within each 'difficulty' and a greater difference between them. The numbers were presented auditorily by an Edison dictaphone connected with the speaking tube which led to the observer's booth.

The *instruction* was essentially that of the first experiment, except that the questionary was omitted.[15]

The experiments were made in the last part of May and first part of June, 1915. Every observer performed 60 experiments: a reduction from the complete series of 76 necessitated by the ending of the term.

---

[10] *Cf.* pp. 470f.

[11] The method proved less satisfactory than that with the episcotister, *op. cit.* 472f., but was necessitated by the lack of a silent motor.

[12] P. 474. [13] P. 490. [14] P. 491. [15] P. 492.

Results

Table I shows for the Single Task Method the degrees of clearness given in the various reports in relation to the accuracy of the report and the kind and direction of change. It is in every way analogous to Table I of our earlier paper.[16]

Table II shows the same results for the Double Task Method. It may be understood by reference to Table X of the first paper.[17]

Tables I and II give only the number of cases occurring under their rubrics. A comparison of the data is more clearly afforded by Tables III and IV. These tables are the analogues of Tables II[18] and XI[19] in the first paper.

The tables bear out in every detail the findings of our first study. The higher degrees of clearness favor right cases and subjective reports. The Double Task Method brings a greater range of degrees of clearness.

The weighted summaries of Tables V and VI are obtained from the summaries of Tables III and IV in accordance with the method of weighting laid down in our previous study.[20] Tables V and VI are analogous to Tables III[21] and XII[22] of that study. As in our former work, we see that the crests of the curves of the right judgments lie, in the case of either method, above the crests of the curves of the wrong judgments. We have thus reestablished the relation between introspectively distinguished variations of clearness and accuracy of work performed.

---

[16] Pp. 474ff.
[17] Pp. 494ff.
[18] Pp. 478ff.
[19] Pp. 496ff.
[20] P. 481.
[21] P. 481.
[22] P. 499.

TABLE I
(Single Task Method)
NUMBER OF REPORTS, CLEARNESS OF MENTAL PROCESSES AT TIME OF CHANGE, ACCURACY OF REPORT, AND KIND AND DIRECTION OF CHANGE

Report	Kind	Direction	O.	RIGHT							WRONG						
				10–9	9–8	8–7	7–6	6–5	5–4	4–3	10–9	9–8	7–8	7–6	6–5	5–4	4–3
KIND AND DIRECTION	INTENSITY	weaker	G	14	16	6	2						2				
			C	11	9	3	1							1			
			Gn	15	13	4	1	1									
		stronger	G	21	8	4	4									1	
			C	21	4	1	1	1	2			1		1			
			Gn	20	14	5	1	4			1	1		1			
	EXTENSITY	smaller	G	19	8	3		1					2	1	1	1	
			C	23	2	2							2	3	2	2	
			Gn	5	16	4	3				3		3	1	2	2	
		larger	G	17	10	5	2						1	1			
			C	24	4							1			4	2	
			Gn	11	7	4	1	3	1			1	1	2			
KIND	INTENSITY	weaker	G		1	1			1		1	1	2	1			
			C	1	3	1	2		3			2		1	1	1	
			Gn			1	3								1		
		stronger	G	1			1		1		1	1	3	2			
			C	1	1	2	3						1	1	1	1	
			Gn			2					1	1					
	EXTENSITY	smaller	G	1	2	1	1	1			2	3		2			
			C	2	1	1						1		1	1		
			Gn	1				1				4		2		2	
		larger	G		2							1	4	4			
			C			1	2	2					3		1		
			Gn								3	11		2			
DIRECTION	INTENSITY	weaker	G	1	1	2	1					1	1			1	
			C		2		1	1	1		1	3	1	2		3	
			Gn					1					1	3			
		stronger	G	1	1	3	2				1			1		1	
			C			1	1	1	1		1	1	2	3			
			Gn	1	1								2				
	EXTENSITY	smaller	G	2	3		2				1	2	1	1	1		
			C		1		1	1			2	1	1				
			Gn		4		2		2		1				1		
		larger	G		1	4	4					2					
			C			3		1					1	2	2		
			Gn	3	11		2										

TABLE I—(*Continued*)

Kind	Direction	O.	SUBJECTIVE							NO-REACTION						
			10–9	9–8	8–7	7–6	6–5	5–4	4–3	10–9	9–8	8–7	7–6	6–5	5–4	4–3
INTENSITY	weaker	G											1	1	1	
		C	2									1	2	2	8	
		Gn		1		1						4	3	3	3	
	stronger	G	2											1		
		C		1						1	1	1	1	1	3	
		Gn											1			
EXTENSITY	smaller	G		1										1		
		C		1							1	2	1		4	
		Gn										1	1		1	
	larger	G													1	
		C	2											2	7	
		Gn		1								2	3			

TABLE II
(Double Task Method)
NUMBER OF REPORTS, CLEARNESS OF MENTAL PROCESSES AT TIME OF CHANGE, ACCURACY OF REPORT, AND KIND AND DIRECTION OF CHANGE

Report	Kind	Direction	O.	RIGHT									WRONG								
				10-9	9-8	8-7	7-6	6-5	5-4	4-3	3-2	2-0	10-9	9-8	8-7	7-6	6-5	5-4	4-3	3-2	2-0
KIND AND DIRECTION	INTENSITY	weaker	G				2	1											5	7	
			C	1		1	1	1										1	1			
			Gn			1	1		1													
		stronger	G			1	1												3	4	
			C		2					1						1				1	
			Gn			2	4	3	3	1	1								5	4	
	EXTENSITY	smaller	G	1	1	2	1							1		1	2		4	3	
			C				1									1				1	
			Gn	5						1	1								7	2	1
		larger	G	1		1				1	1					2		1	5	4	
			C												1	1	1	1		2	
			Gn	2		2	1										1		1	2	1
KIND	INTENSITY	weaker	G					1	2	1	1						1				
			C		1			1		1				1	1	1					
			Gn				1														
		stronger	G				1	1	1	1	1							1			
			C			1								3	3	2	1				
			Gn					1		1	2										
	EXTENSITY	smaller	G		1		1			2							2				
			C	1										1		1					
			Gn				1									1	1		1		
		larger	G		1		1				1			1		2					
			C											2		2					
			Gn					1			1					3	2		1		
DIRECTION	INTENSITY	weaker	G					1									1	2	1	1	
			C		1	1	1							1			1		1		
			Gn													1					
		stronger	G						1							1	1	1	1	1	
			C		3	3	2	1							1						
			Gn														1		1	2	
	EXTENSITY	smaller	G					2						1		1			2		
			C		1		1						1								
			Gn				1	1		1						1					
		larger	G		1		2							1		1				1	
			C		2		2														
			Gn				3	2		1							1			1	

TABLE II—(*Continued*)

Kind	Direction	O.	SUBJECTIVE									NO-REACTION								
			10-9	9-8	8-7	7-6	6-5	5-4	4-3	3-2	2-0	10-9	9-8	8-7	7-6	6-5	5-4	4-3	3-2	2-0
INTENSITY	weaker	G															2		4	11
		C	1													2	1		5	18
		Gn																3	10	18
	stronger	G														2	1	3	4	9
		C				1										1	2	2	2	13
		Gn																	5	5
EXTENSITY	smaller	G																1	5	6
		C														1	1	4	5	10
		Gn																	12	9
	larger	G															1	2	6	7
		C													2		1	3	3	15
		Gn															1		10	10

TABLE III

(Single Task Method)

NUMBER OF CASES GROUPED ACCORDING TO THE KIND AND DIRECTION OF THE OBJECTIVE CHANGE; THE ACCURACY OF THE OBSERVER'S REPORTS; AND THE CLEARNESS OF THE MENTAL PROCESSES AT THE TIME OF CHANGE; WITH SUMMARY.

Kind or Direction	Report	O.	Clearness						
			10–9	9–8	8–7	7–6	6–5	5–4	4–3
Intensity	Right	G	36	25	11	7		2	
		C	34	17	7	7	1	5	
		Gn	35	27	12	5	5		
	Wrong	G	2	2	7	4		1	
		C		3	1	4	2	2	
		Gn	2	2		1	1		
	Subjective	G	2						
		C	2	1					
		Gn		1		1			
	No reaction	G				1	2	1	
		C	1	1	2	3	3	11	
		Gn			4	4	3	3	
Extensity	Right	G	37	22	9	3	2		
		C	49	7	4	2	2		
		Gn	17	23	8	4	4	1	
	Wrong	G	2	4	7	8	1	1	
		C		2	5	4	8	4	
		Gn	6	16	4	7	2	4	
	Subjective	G		1					
		C	2	1					
		Gn		1					
	No reaction	G					1	1	
		C		1	2	1	2	11	
		Gn			3	4		1	
Weaker or Smaller	Right	G	36	28	11	5	1		
		C	34	14	5	3	2	1	
		Gn	20	33	8	6	2	2	
	Wrong	G	1	3	6	2	2	2	
		C	3	4	4	6	2	5	
		Gn	4		4	4	3	2	
	Subjective	G		1					
		C	2	1					
		Gn		1		1			
	No reaction	G				1	2	1	
		C		1	3	3	2	12	
		Gn			5	4	3	4	
Larger or Stronger	Right	G	39	20	16	12			
		C	45	8	5	2	3	3	
		Gn	35	33	9	4	7	1	
	Wrong	G	1	2	1	3		2	
		C	1	3	3	6	6	2	
		Gn	1	2	3	3			
	Subjective	G	2						
		C	2	1					
		Gn		1					
	No reaction	G					1	1	
		C	1	1	1	1	3	10	
		Gn			2	4			

TABLE III—(*Continued*)

Kind or Direction	Report	O.	Clearness 10–9	9–8	8–7	7–6	6–5	5–4	4–3
Summary	Right	G	148	95	47	27	3	2	
		C	162	46	21	14	8	9	
		Gn	107	116	37	19	18	4	
	Wrong	G	6	11	21	17	3	6	
		C	4	12	13	20	18	13	
		Gn	13	20	11	15	6	6	
	Subjective	G	4	2					
		C	8	4		[illegible]			
		Gn		4					
	No reaction	G				2	6	4	
		C	2	4	8	8	10	44	
		Gn			14	16	6	8	

TABLE IV

(Double Task Method)

Number of Cases Grouped According to the Kind and Direction of the Objective Change; the Accuracy of the Observer's Reports; and the Clearness at Time of Change; with Summary.

Kind and Direction	Report	O.	Clearness 10–9	9–8	8–7	7–6	6–5	5–4	4–3	3–2	2–0
Intensity	Right	G			1	4	3	3	2	2	
		C	1	3	2	1	2		2		
		Gn			3	6	4	4	2	3	
	Wrong	G					1	1	8	11	
		C		4	4	4	1	1	1	1	
		Gn							5	4	
	Subjective	G									
		C	1		1						
		Gn									
	No reaction	G					2	3	3	8	20
		C					3	3	2	7	31
		Gn							3	15	23
Extensity	Right	G	2	3	3	3			3	2	
		C	8		1	2					
		Gn			2	1	1		1	2	
	Wrong	G		2		5	4	1	9	7	
		C		3	1	5	1	1		3	1
		Gn				4	4		10	4	1
	Subjective	G									
		C									
		Gn									
	No reaction	G						1	3	11	13
		C				2	1	2	7	8	25
		Gn						1		22	19

TABLE IV—(*Continued*)

Kind and Direction	Report	O.	Clearness 10–9	9–8	8–7	7–6	6–5	5–4	4–3	3–2	2–0
Smaller or Weaker	Right.....	G	1	1	2	3	4				
		C	6	2	2	4	1				
		Gn			1	2	1	1	2	1	
	Wrong.....	G				2	3	2	12	11	
		C	1	2		1	1	1	2	1	
		Gn		1		2			7	2	1
	Subjective....	G									
		C	1								
		Gn									
	No reaction...	G						2	1	9	17
		C					3	2	4	10	28
		Gn							3	22	27
Larger or Stronger	Right.....	G	1	1	2	3		1	1	1	
		C	2	7	4	5	1		1		
		Gn			4	7	5	3	2	1	
	Wrong.....	G		1		4	1	2	9	10	
		C			2	2	1	1		3	1
		Gn					3		7	9	
	Subjective....	G									
		C			1						
		Gn									
	No reaction...	G					2	2	5	10	16
		C				2	1	3	5	5	28
		Gn						1		15	15
Summary	Right.....	G	4	5	8	13	7	4	6	5	
		C	17	12	9	12	4		3		
		Gn			10	16	11	8	7	7	
	Wrong.....	G		5		11	9	6	38	39	
		C	1	8	7	12	4	4	3	8	2
		Gn				6	7		29	19	2
	Subjective....	G									
		C	2		2						
		Gn									
	No reaction...	G					4	8	12	38	66
		C				4	8	10	18	30	112
		Gn						2	6	74	84

TABLE V

(Single Task Method)

Weighted Summaries

O.	Reports	Clearness 100–90	90–80	80–70	70–60	60–50	50–40
G	Total right.....	148.0	95.0	47.0	27.0	3.0	2.0
	Total wrong.....	10.0	13.0	21.0	19.5	10.5	11.0
C	Total right.....	162.0	46.0	21.0	14.0	8.0	9.0
	Total wrong.....	14.5	21.0	23.0	30.0	30.5	68.0
Gn	Total right.....	107.0	116.0	37.0	17.0	18.0	4.0
	Total wrong.....	13.0	24.0	28.5	37.0	13.5	16.0

TABLE VI

(Double Task Method)

WEIGHTED SUMMARIES

O.	Reports	CLEARNESS								
		100-90	90-80	80-70	70-60	60-50	50-40	40-30	30-20	20-00
G	Total right.....	4.0	5.0	8.0	13.0	7.0	4.0	6.0	5.0	
	Total wrong. ...		5.0		16.0	15.0	22.0	53.0	86.5	82.5
C	Total right.....	17.0	12.0	9.0	12.0	4.0		3.0		
	Total wrong. ...	3.0	8.0	9.0	17.0	14.5	16.5	25.5	45.5	142.5
Gn	Total right.....			10.0	16.0	11.0	8.0	7.0	7.0	
	Total wrong. ...				6.0	7.0	2.5	36.5	111.5	107.0

SPECIAL POINTS

(1) The *relation between the observers' reports and the kind and direction of objective change* is shown in Tables VII and VIII, which correspond respectively to Tables IV[23] and XIII[24] of the first study. Table VII shows for all observers that more intensive than extensive changes are correct, that intensive changes are more attention-compelling than extensive, and that changes to a larger and stronger cutaneous stimulus are more compelling than changes to a smaller and weaker. Table VIII does not show a uniform tendency; the work in the Double Task Method was probably not influenced by anything else than fluctuation of attention.

(2) The *promptness of voluntary action* as a measure of attention[25] is shown, irrespectively of the correctness of the judgments, in Tables IX and X (analogous to Tables V[26] and XIV[27] of the first paper).

TABLE VII

(Single Task Method)

RELATION BETWEEN THE OBSERVER'S REPORTS AND THE KIND AND DIRECTION OF THE OBJECTIVE CHANGES

O.	KIND								DIRECTION							
	INTENSITY				EXTENSITY				DOWN				UP			
	R.	W.	S.	N.	R.	W.	S.	N.	R.	W.	S.	N.	R.	W.	S.	N.
G	81	16	2	4	73	23	1	2	81	16	1	4	87	9	2	2
C	71	12	3	21	64	23	3	17	59	24	3	21	66	21	3	17
Gn	84	6	2	14	57	39	1	8	71	17	2	16	89	9	1	6
Total	236	34	7	39	194	85	5	27	211	57	6	41	242	39	6	25

Down, smaller or weaker. Up, larger or stronger. R., right. W., wrong. S., subjective. N., no-reaction.

[23] P. 482. [24] P. 501.

[25] *Cf.* H. Woodrow, *Psychol. Rev. Monog. Suppl.*, XVII, no. 5, who asserts "that reaction time may vary without corresponding variation in attention" (p. 139), yet admits that "the absolute increase in reaction time produced by the use of unfavorable intervals as a distractor varies inversely as the degree of attention" (pp. 12, 98).

[26] P. 484. [27] P. 501.

TABLE VIII

(Double Task Method)

RELATION BETWEEN THE OBSERVER'S REPORTS AND THE KIND AND DIRECTION OF THE OBJECTIVE CHANGES

O.	KIND								DIRECTION							
	INTENSITY				EXTENSITY				DOWN				UP			
	R.	W.	S.	N.	R.	W.	S.	N.	R.	W.	S.	N.	R.	W.	S.	N.
G	15	21	..	36	16	28	..	28	11	32	..	29	10	27	..	35
C	11	16	2	46	11	15	..	45	15	8	1	47	20	10	1	44
Gn	22	9	..	41	7	23	..	42	8	12	..	52	22	19	..	31
Total	48	46	2	123	34	66	..	115	34	52	1	128	52	56	1	110

Down, smaller or weaker. Up, larger or stronger. R., right. W., wrong. S., subjective. N., no-reaction.

TABLE IX

(Single Task Method)

AVERAGE REACTION-TIME OF THE OBSERVER'S REPORT IN SECONDS AT THE DIFFERENT LEVELS OF ATTENTION

O.		CLEARNESS								
		100–90	90–80	80–70	70–60	60–50	50–40	40–30	30–20	20–00
G	Av. R.	1.19	1.18	1.34	1.55	1.93				
	m. v.	.34	.32	.35	.45	.43				
	No.	73	49	23	21	3				
C	Av. R.	1.20	1.47	1.66	1.51	1.80	2.30			
	m. v.	.38	.45	.52	.50	.73	.82			
	No.	91	13	16	13	7	9			
Gn	Av. R.	1.04	.94	1.20	1.25	1.09	1.29			
	m. v.	.32	.28	.51	.44	.20	.25			
	No.	41	71	14	12	10	7			

Av. R. average reaction time. m. v., mean variation. No., number of cases.

TABLE X

(Double Task Method)

AVERAGE REACTION-TIME OF THE OBSERVER'S REPORT IN SECONDS, AT THE DIFFERENT LEVELS OF ATTENTION

O.		CLEARNESS								
		100–90	90–80	80–70	70–60	60–50	50–40	40–30	30–20	20–00
G	Av. R.	0.70	0.95	0.60	0.79	0.95	0.87	1.68	1.50	
	m. v.	.30	.40	.20	.38	.31	.27	.92	.75	
	No.	2	6	4	13	6	7	18	17	
C	Av. R.	1.32	1.30	1.42	1.80	1.47		.80	2.57	1.90
	m. v.	.66	.40	.78	.82	.96		.00	1.37	.00
	No.	10	5	8	7	4		2	4	1
Gn	Av. R.			1.02	0.98	0.97	1.17	1.18	0.99	1.40
	m. v.			.44	.30	.19	.41	.37	.11	.00
	No.			5	12	8	4	15	12	1

Av. R., average reaction time. m. v., mean variation. No., number of cases.

The coefficients of correlation (figured by Pearson's 'product moments' method) and the probable error are, for the Single Task Method:

O.	Correlation	P.E.
G	—0.98	0.011
C	—0.64	0.162
Gn	—0.70	0.140

and for the Double Task Method:

O.	Correlation[28]	P.E.
G	—0.74	0.101
C	—0.91	0.047
Gn	—0.33	0.247

These results corroborate those which we obtained in our first paper, and lead us to the conclusion that reactions of this sort are reliable indices of attention.

(3) In our earlier study we pointed out that the *mean variation* has frequently been used as a measure of attention, and our results at that time tended to confirm such a view. The results of the present study, however, are not conclusive. The correlation between the mean variations and the degrees of clearness, the data of which appear in Tables IX and X, is (Pearson's method) for the Single Task Method:

O.	Correlation	P.E.
G	—0.85	0.063
C	—0.94	0.023
Gn	+0.30	0.239

and for the Double Task Method:

O.	Correlation[29]	P.E.
G	—0.65	0.115
C	—0.83	0.064
Gn	+0.29	0.242

The figures for G and C corroborate our previous findings,[30] whereas Gn's results are contradictory. The difference may be due to the different interpretation that Gn placed upon his instructions, and also to the fact that he frequently reported change without being able to tell the kind or direction.[31] As the delayed reactions show, he did not interpret the directions to mean "react as quickly as possible", but merely "react in order to report." The reactions might therefore be made at his convenience. It is possible that, in the changes which were clear, he sometimes delayed his replies until he was absolutely certain both as to Kind and as to Direction, while at other times he reacted as soon as

[28] In the computation of these correlations the data under the 7th and 9th rubrics for C, and the 9th rubric for Gn, were omitted because they represented too few cases: 2, 1, and 1 cases respectively.

[29] See preceding foot-note.

[30] Pp. 485, 502.

[31] Such reports were counted as wrong as to both Kind and Direction, and two points were added to the wrong replies in the weighted results. A half point was thereby credited to the observer; for, had he not noted the fact of change, 2.5 points would have been added to the side of 'wrong.'

the change was perceived (this would account for the small reaction times and the large mean variation in the high degrees of clearness); and that, in the changes which were obscure, he always reacted as soon as he became aware of the changes, because, no matter how long he delayed, they were too obscure for him to tell kind or direction (this would account for the long reaction times and the small variations of the low degrees of clearness). We cannot offer more than this general and hypothetical explanation of the discrepancy.

(4) The *relation of the reaction times to the Kind and Direction of the objective change* appears for the two methods in Tables XI and XII, which correspond to Tables VI[32] and XV[33] of the first study.

TABLE XI

(Single Task Method)

RELATION BETWEEN THE OBSERVER'S REACTION TIME IN SECONDS AND THE KIND AND DIRECTION OF THE OBJECTIVE CHANGE

O.	KIND						DIRECTION					
	INTENSITY			EXTENSITY			DOWN			UP		
	Av.	m.v.	No.	Av.	m.v.	No.	Av.	m.v.	No.	Av.	m.v.	No.
G	1.28	.40	82	1.25	.32	87	1.29	.38	82	1.24	.39	87
C	1.54	.55	73	1.27	.43	76	1.42	.48	76	1.39	.52	73
Gn	1.06	.38	71	1.02	.27	84	1.09	.37	73	.98	.33	82

Av., average reaction time. m.v., mean variation. No., number.

TABLE XII

(Double Task Method)

RELATION BETWEEN THE OBSERVER'S REACTION-TIME IN SECONDS AND THE KIND AND DIRECTION OF THE OBJECTIVE CHANGE

O.	KIND						DIRECTION					
	INTENSITY			EXTENSITY			DOWN			UP		
	Av.	m.v.	No.	Av.	m.v.	No.	Av.	m.v.	No.	Av.	m.v.	No.
G	1.31	.78	34	1.05	.47	39	1.21	.68	40	1.14	.57	33
C	1.66	.78	24	1.66	.90	17	1.55	.89	20	1.77	.89	21
Gn	1.08	.29	30	.98	.19	27	1.07	.27	18	1.02	.22	39

Av., average reaction time. m.v., mean variation. No., number.

Tables II and IV show that there is a positive correlation between variation in attention and accuracy of work, regardless of the kind and direction of the objective change. We have seen, nevertheless, from Tables VII and VIII, that intensive changes are more compelling than extensive, and that changes to a greater are more compelling than changes to a smaller. This relation is only partially confirmed by the reaction times, as is shown by Tables XI and XII above. If we assume that the most compelling changes give the shortest reaction time, then we must say that the reaction times show that extensive changes and

[32] P. 486. [33] P. 502.

changes to the greater are the most compelling, since the average reaction times and mean variations are larger for intensity than for extensity and larger for changes to a smaller than to a greater. The relation is not absolute, for C in the Double Task Method has the same average reaction time for both the intensive and extensive changes, and a shorter reaction for the changes to a smaller than to a greater. The difference is, however, in no case great and shows once more that the work in these experiments was not influenced by anything else than fluctuation of attention.

(5) A comparison of Tables VII and XI with Tables VIII and XII shows that there is a close correlation between the *reaction time and the accuracy of report*. This relation is more clearly shown in Tables XIII and XIV (*cf.*, in the first paper, Tables VII[34] and XVI[35] respectively), in which the reaction times are compared directly with the accuracy of the reports. The results agree with those previously reported.

TABLE XIII

(Single Task Method)

THE REACTION-TIME IN SECONDS AND THE MEAN VARIATION OF THE RIGHT, HALF-RIGHT, AND WRONG REPORTS

Observer	RIGHT			HALF-RIGHT			WRONG		
	Av.	m.v.	No.	Av.	m.v.	No.	Av.	m.v.	No.
G	1.27	.33	127	1.33	.35	33	1.44	.15	9
C	1.38	.41	111	1.50	.45	26	1.84	.70	12
Gn	.97	.28	108	1.21	.49	36	1.26	.37	11

Av., average reaction-time. m.v., mean variation. No., number.

TABLE XIV

(Double Task Method)

THE REACTION-TIME IN SECONDS AND THE MEAN VARIATION OF THE RIGHT, HALF-RIGHT, AND WRONG REPORTS

Observer	RIGHT			HALF-RIGHT			WRONG		
	Av.	m.v.	No.	Av.	m.v.	No.	Av.	m.v.	No.
G	0.71	.19	15	1.18	.58	40	1.62	1.02	18
C	1.36	.58	10	1.48	.76	24	2.33	1.08	7
Gn	0.98	.30	20	1.05	.23	13	1.06	.19	24

Av., average reaction-time. m.v., mean variation. No., number.

(6) The *effect of the distractors* used in the Single Task Method is shown in Table XV (with which *cf.* Table VIII of the other study[36]).

[34] P. 486. [35] P. 503.
[36] P. 487, with which *cf.* p. 472.

TABLE XV

(Single Task Method)

THE AVERAGE CLEARNESS OF THE CUTANEOUS SENSATIONS AS AFFECTED BY THE DISTRACTORS

O.		DISTRACTOR						
		0	1	2	3	4	5	6
G	Av. C.	85.5	81.6	84.3	83.8	82.9	76.3	73.5
	m.v.	4.1	9.2	7.4	7.2	5.8	12.2	13.0
	No.	30	22	31	33	31	18	34
C	Av. C.	87.2	75.0	84.0	70.2	85.0	77.1	65.0
	m.v.	14.3	22.3	16.4	22.0	13.2	20.4	27.1
	No.	36	22	31	36	31	18	34
Gn	Av. C.	94.7	70.0	78.8	71.1	85.3	77.6	82.5
	m.v.	1.7	14.8	7.2	13.3	7.0	6.8	8.7
	No.	36	22	31	36	31	18	34

Av. C., average clearness of cutaneous sensations. m.v., mean variation. No., number of cases. 0, normal conditions. 1, flicker. 2, buzzer. 3, bell. 4, metronome. 5, flicker and buzzer. 6, phonograph.

The table shows that the distractors were not especially effective, that there was a wide variation from day to day in their effectiveness, and that there was a great difference in their effect upon the different observers. We have already discussed the factors upon which these points depend in our previous paper.[37] The last point is exhibited in Table XVI (corresponding to Table IX of the first paper [38]).

TABLE XVI

(Single Task Method)

THE ORDER OF THE EFFECTIVENESS OF THE DISTRACTORS FROM LEAST TO GREATEST AS DETERMINED BY THE AVERAGE CLEARNESS OF THE CUTANEOUS SENSATIONS

Observer	ORDER						
	1	2	3	4	5	6	7
G	0	2	3	4	1	5	6
C	0	4	2	5	1	3	6
Gn	0	4	6	2	5	3	1

0, normal. 1, flicker. 2, buzzer. 3, bell. 4, metronome. 5, flicker and buzzer. 6, phonograph.

(7) The *effect of the secondary tasks upon attention* is shown in Table XVII, which corresponds to Table XVII of our earlier work.[39]

[37] Pp. 489f. [38] P. 488. [39] P. 504.

TABLE XVII

(Double Task Method)

THE AVERAGE CLEARNESS OF THE CUTANEOUS SENSATIONS AS AFFECTED BY THE DIRECTION OF ATTENTION ON THE PRIMARY OR SECONDARY TASK

Observer		Attention Directed To		
		0	1	2
G	Av. C.	92.0	22.5	44.3
	m.v.	6.30	15.19	25.47
	No.	36	75	69
	Av. R.	1.02	1.32	1.11
C	Av. C.	95.0	32.8	23.9
	m.v.	4.30	15.57	19.57
	No.	36	75	69
	Av. R.	1.10	1.57	1.69
Gn	Av. C.	95.0	18.4	21.2
	m.v.	3.33	8.56	11.45
	No.	36	75	69
	Av. R.	.78	1.12	.90

Av. C., average clearness of cutaneous sensations. m.v., mean variation. No., number of cases. 0, attention directed to cutaneous sensations. 1, attention directed to adding processes. 2, attention directed to subtracting processes. Av. R., average reaction time for experiments under each rubic.

The results are like those of the previous paper. They show the effect of the division of attention. In the normal or control experiments, the average clearness of the cutaneous sensations is uniformly higher, the mean variation is uniformly smaller, and the reaction time is uniformly shorter than is the case in the Double Task experiments.

(8) Table XVIII shows the *relation between the character and quality of the work performed, and attention* as introspectively estimated in terms of attributive clearness (Table XVIII of the first article [40]).

TABLE XVIII

(Double Task Method)

COMPARISON BETWEEN THE AVERAGE CLEARNESS OF THE MENTAL PROCESSES INVOLVED IN CONTINUOUS ADDING; IN CONTINUOUS SUBTRACTING; AND THE ACCURACY OF THE WORK PERFORMED

O.	Report	Mental Process											
		Adding—Clearness						Subtracting—Clearness					
		10-9	9-8	8-7	7-6	6-5	5-4	10-9	9-8	8-7	7-6	6-5	5-4
G	Correct.	2						4	1				
	Nearly correct.	4	2	2				6	1				
	Failure.	3	3	4	3	2		1	3		2	5	
	No. cases.	9	5	6	3	2		11	5		2	5	
C	Correct.	2											
	Nearly correct.	4	3	1	1	1		4	2				
	Failure.	4	1	5		3		4	2	3	2	6	
	No. cases.	10	4	6	1	4		8	4	3	2	6	
Gn	Correct.	1	1										
	Nearly correct.	2	3	1				1	1				
	Failure.	3	10	1	2	1		4	7	7	2	1	
	No. cases.	6	14	2	2	1		5	8	7	2	1	

[40] P. 504.

The results are those that we have learned to expect; more correct answers and fewer failures were returned during the higher degrees of clearness than in the lower. We have evidence once more, therefore, that introspectively distinguished variations of clearness are closely paralleled by corresponding differences in the accuracy of the work performed.

(9) In working over the data for information concerning the *number of levels* of attentive consciousness, we have included the introspections of L. B. Hoisington, given during the preliminary training and practice periods. H's work was cut short by mid-year graduation, and his results were for that reason not reported in the other connections. He gave in the preliminary training and practice periods 189 reports; which, with those of the other observers, make up a total of 1175.

The observers reported without exception the dual division of consciousness; that is to say, a clear focus and a vague background, which varied reciprocally.[41] The introspective values for the upper and lower levels of clearness did not in every case total 100, but the discrepancy was never very large. It was never more than five degrees the one way or the other, and more often smaller than larger.

Summary

Our conclusions, based upon the present work with extent and intensity of cutaneous sensation, substantiate the conclusions which we have printed for the work with pitch and intensity of auditory sensation.[42] The reader is referred to the previous Summary.

We find again that the Double Task or division method gives a greater variation in the range of attention than does the Single Task or distraction method.[43] Thus we may conclude that the Double Task method is the more effective.

Concerning the relation of intensive to extensive changes, we may now conclude that intensive changes and changes to a greater intensity or extent are slightly more compelling than are extensive changes and changes to a smaller intensity or extent.

[41] *Op. cit.*, p. 506. [42] *Op. cit.*, 507. [43] *Op. cit.*, 490.

VISUAL IMAGERY AND ATTENTION: AN ANALYTICAL STUDY[1]

By Helen Clark

I. Introduction

Ever since the appearance of Galton's "Inquiries into Human Faculty,"[2] the subject of imagery has received almost constant attention from psychologists, and, moreover, its cultivation has been strongly marked by an increasing diversity of new problems. It is not necessary to pass the general literature of the subject in review; but we shall briefly mention those phases of it which are most closely related to the present study. First of all, we must note that the current tendency to view mind in its historical aspects has prompted the psychologist to seek for the *antecedents* of the image; to discover, that is to say, its dependence upon perception. Experimentalists now generally "incline to the view that there is no intrinsic difference between sensation and image."[3] Investigations in the field of suggestion reveal the fact that, under certain circumstances, simple or total images may be mistaken for sensations or perceptions.[4] On the other hand, "a visual perception of distinctly supraliminal value may . . . pass—even with specially trained observers—for an image."[5] Related studies have dealt with the *development* and the *decay* of imaginal complexes in the course of time. The associationists' conception of stable psychical entities has been discarded, and the view commonly held at present is that "the memory is not to be regarded as a storehouse of perfectly conserved images, but that the most simple memories are continually exposed to change, and that it is, at times, only by the combination of various memorial re-

[1] From the Psychological Laboratory of the University of Illinois.

[2] Galton, F., Inquiries into Human Faculty and its Development, 1883.

[3] Perky, C. W., An experimental study of imagination, *Amer. J. of Psychol.*, 1910, xxi, 435. Cf. Külpe, O., *Philos. Stud.*, xix, 508ff., and Washburn, M. F., *Mind*, n. s., viii, 1899, 32.

[4] Cf. Seashore, C. E., Measurements of illusions and hallucinations in normal life, *Studies from the Yale Psychological Laboratory*, 1893-97, i-v, 32.

[5] Perky, *op. cit.*, p. 435.

sources that retention is made definite and exact."[6] Experimental and theoretical inquiries have also been directed toward the *general functions* of the image in relation to thought and meaning,[7] discrimination and judgment,[8] and reproduction and recognition.[9] Moreover, there have been several attempts made at *classification* of total images on a basis of divers characteristics, usually functional. Visual images have here received most consideration. Four important investigations which have recently appeared are those of Perky,[10] L. J. Martin,[11] K. Koffka,[12] and R. M. Ogden.[13] And finally, images have been studied in their relations to motor phenomena, especially to *ocular movement*.[14]

The problems and methods in Ogden's and in Perky's investigations closely resemble those of our own experiments. There are, however, three important differences. (1) Both Ogden and Perky discovered a number of intermediate or "equivocal" images[15] which did not seem to belong either among their "images of imagination" or with their "images of memory." We decided to include in our classification all non-verbal (or primary) images which were reported by our observers. (2) As regards ocular movement, Ogden obtained negative results (p. 381); while Perky, by means of another procedure, discovered a striking correspondence between the kind of image and the occurrence of ocular movements (pp.

[6] Bentley, M., The memory image and its qualitative fidelity, *Amer. J. of Psychol.*, 1899, xi, 47f. Cf. Philippe, J., L'image mentale; evolution et dissolution. Paris, 1903, 76ff, 116f.

[7] Cf. Betts, G. H., *The distribution and functions of mental imagery*. Teachers College, Columbia University, 1909, p. 41.

[8] Cf. Whipple, G. M., An analytical study of the memory image and the process of judgment in the discrimination of clangs and tones, *Amer. J. of Psychol.*, 1901, xii, 409ff.

[9] Bentley, M., *op. cit.*, 46.

[10] *Op. cit.*

[11] Die Projecktionsmethode und die Lokalisation visueller und anderer Vorstellungsbilder, *Zsch. f. Psychol.*, 1913, lxi, 321.

[12] *Zur Analyse der Vorstellungen und ihrer Gesetze*, Leipzig, 1912.

[13] Experimental criteria for differentiating memory and imagination in projected visual images, *Psychol. Rev.*, 1913, xx, 378.

[14] Perky, *op. cit.*, and Ogden, *op. cit.* Cf. Meakin, F., Mutual inhibition of memory images, *Harvard Psychological Studies*, i, 1903, 244; Moore, C. S., Control of the memory image, *ibid.*, 296; Slaughter, J. W., Behavior of mental images, *Amer. J. of Psychol.*, xiii, 1902, 548; Kuhlmann, F., Analysis of the memory consciousness, *Psychol. Rev.*, xiii, 1906, 338f; Murray, E., Peripheral and central factors in memory images, *Amer. J. of Psychol.*, xvii, 1906, 241; Külpe, *Outlines*, 1909, 187; Burtt, H. E., Factors which influence the arousal of the primary visual memory image, *Amer. J. of Psychol.*, xxvii, 1916, 87.

[15] Ogden, p. 406; Perky, 436.

442, 451). We decided to observe movements of the eyes by three different methods, one of them being somewhat similar to Perky's. (3) We proposed to discover, if possible, the *factor or factors most closely connected with ocular movements,* not simply the sort of image which was usually involved.[16]

Before proceeding to the account of our experiments, we must observe that the term "image" is ambiguous. As it is used by psychologists to-day, it stands for (1) a mental process, (2) a group or constellation of mental processes, (3) a kind of reference or meaning, and (4) a particular sort or class of objects. As regards the first two meanings, we shall distinguish the "simple image" (a single imaginal process taken at the level of sensation and affection) from the "total image" (the single imaginal constellation or complex); and so far as the functional treatment of imagery is concerned,—the treatment which discovers such marks as "particularity," "locality," and "personal reference,"—we shall try to make clear in the context when we are dealing with meanings and objects and when we intend to indicate processes. The attempt is worth while because it is still frequently assumed, even by serious writers, that the imaged object is a "mental" object and so ultimately different for the psychologist from the physical objects of perception.

II. Experimental: An Analysis of Visual Imagery

Problem and method. Our first investigation was an analytical study of the visual images aroused by a series of words. The purpose of the experiment was to obtain a descriptive account of the images evoked with respect to twelve different characteristics, to classify the images with reference to two of these peculiarities, and to discover whether there was a resemblance in other details among the images of each group.

There were two observers, A and B. O[17] was seated in a dark room facing a black wall. The experimenter took her place behind the observer at a table provided with a shaded light for the recording

[16] Our observers, named in the order in which they served in the experiments, were: an advanced undergraduate—Miss B. V. Copley (A); two graduate students—Mr. C. E. Holley (B), and Miss A. S. Rogers (C); three instructors in psychology—Dr. C. A. Ruckmich (D), Dr. J. E. DeCamp (E), and Dr. C. Rahn (F). The author wishes to express her grateful appreciation of their services and to acknowledge her especial indebtedness to Professor Bentley, under whose supervision the investigation was pursued.

[17] "O" has been used in the following pages as an abbreviation for "observer."

of O's descriptions. The experimenter transcribed O's account as O dictated. For evoking the images, 114 substantives were used with A; with B, 75 words taken from the same list.[18] The instructions were as follows: "After a signal 'ready,' I shall pronounce a word. You are to note any visual image that may occur. As soon as it has disappeared, give a full description of it."

It is to be observed that the instructions were quite general. The subject was not *required* to call up an image, but merely to note any that should occur. Furthermore, the image was not supposed to be that of a particular object, but simply any visual image. The subject was not asked voluntarily to hold the image, which was to take its natural course.

The description was not interrupted; but, when O had finished his account, he was questioned as to any points which he had overlooked. The experimenter sought complete information concerning (1) specificity of reference ("particularity"), (2) familiarity, (3) the position of the imaged object in relation to O, (4) the visual background, (5) the size of the imaged object, (6) its stability, (7) the number and the degree of clearness of its details, (8) color, (9) accompanying affective tone, (10) somatic reference, (11) associative processes, and (12) temporal reference.

Results. The images reported were first divided into three main groups. Those which referred to *specified objects* and which were apprehended as *familiar* were called *F-images.* Memory images (those which not only referred to specified objects and were apprehended as familiar, but which also involved a reference to a particular place and to O's past experience), were considered as a sub-class of the F-images. Images which were *specific* and *unfamiliar* were called *U-images.* These were not necessarily accompanied by a feeling of strangeness; there was, in most cases, merely absence of familiarity. Finally, images of *general reference* (signifying a class or a member of a class of objects), which also involved no familiarity, were designated as *G-images.*[19] With regard to position, the imaged objects were classified as *usual* when they had the same position in relation to the observer as the perceptual objects commonly occupied; they were called *unusual* if the position was not characteristic of the perceptual object, or if the imagined object seemed detached from any setting, or if the localization was extremely indefinite. Images were classified as *unstable* if they fluctuated, faded quickly, or were soon replaced by other images. When describing the

[18] Some of the words were: knife, river, dog, church, soap, cloud, grass, king, lyre, Cerberus, druid, tournament, King Arthur, wand, nightingale, baron, Marmion.

[19] Both the generality of reference and the definiteness of spatial orientation we found, as did Koffka, to present a large number of degrees and gradations. These differences seem, however, to be unimportant for our main purpose.

details of images as *many* or *few*, the experimenter took into consideration the amount of detail which corresponding objects revealed in perception. *Color* was described as *absent* if color was normally present in the perceptual mode of the object. We took *associative processes* to mean relevant processes not completely assimilated to the total image. Such associative processes might occur at the same time as the principal image, although they were more apt to appear subsequently. Where the corresponding perception had occurred at some time within a year, the image was classed as *recent*. *Somatic reference*[20] was present in several forms. In some cases, the observer simply was at the place presented in imaginal form.

"The church was in the position in which it would be if I were walking up to it." "Then the image changed as I went inside." "I was there. I seemed to be younger than I am now." "I was lying on my back and looking at the clouds."

Some images stood in definite relation to certain parts of the body.

"The gun was parallel to my arm as though my arm were extended." "The bird was back of my arm at the left. I thought of turning my head and looking at it." "The shoes were on my own feet."

In some cases, the somatic reference was more explicit.

"I imagined myself as there." "I seemed to be coming along the walk." "I knew that I was there."

In one case, the subject had a definite visual image of herself.

"I saw myself take the key out of the rubber where it is kept."

[20] The word "somatic" is used to avoid the ambiguous term "personal." Perky uses, without definition (p. 436), "personal reference" as one of her two cardinal distinctions between "images of memory" and "images of imagination." We mean by "somatic reference" that the observer apprehended the imaged object as related to his own perceived or imaged body. The words "personal reference" might have a similar significance; but they might also imply a reference to the observer's past experience. Our own analyses seem to indicate that "particularity," Perky's second cardinal distinction, is—even when taken with the first—an unsatisfactory mark of memory. We found many particular and specified objects which could not, save by the most arbitrary designation, be called "memories." Similar criticism upon these terms has been passed by Koffka (p. 226) and Ogden (p. 384ff). Perky's determination to study "imagination" appears to have induced her to accept, without refined analysis, a "rough and ready criterion" of the simpler imaginal complexes. Although she uses this criterion "for preliminary purposes" (p. 451), it nevertheless determines her whole conception of the simpler processes and modes of integration by which, as she assumes, "imaginations" are built up.

All of these functional distinctions are, of course, more or less crude. They should, however, suffice to reveal any striking dissimilarities existing among our classes.

Table I shows the distribution of the different kinds of images for each observer.

TABLE I

Observers	F-images	G-images		U-images	Totals
	Primary	Primary	Secondary	Primary	
A	36	61	..	43	140
B	36	12	7	4	59
Totals	72	73	7	47	199

Most of the visual images were primary (non-verbal), but some of B's images were secondary or symbolic (verbal). The 7 secondary visual images mentioned in the table appeared as independent total images. They are not included in the following discussion of results unless specifically mentioned.

Table II shows a more detailed analysis of the images. As regards the temporal relations of the F-images, over half (53% and 61%) were referred to objects seen habitually and recently (within a year), while more than a third (36% and 39%) referred to objects perceived on some recent and specific occasion. In 11% of A's F-images there was recognition without definite temporal relations. Under three of the principal headings of classification there seemed to be little or no correspondence between the kind of imagery and a particular characteristic. These headings were color, stability, and size.

1. *Color* was present in all but six images. Three of these were F-images, one was a G-image, and one was a U-image.

2. *Stability* was characteristic of 61% of A's F-images, but only 39% of B's F-images were stable. Of B's G-images 83% were unstable. In the other cases, the percentages are not significant.

3. *Normal size* was reported in from 70% to 100% of the cases in each group. In the case of A, the G-images characterized by abnormal size were three times as numerous as the corresponding F-images, while the abnormal U-images were four times as numerous as the F-images. Of B's images, on the other hand, the F's were the only ones that were ever characterized by abnormal size. These reports, however, may

TABLE II

			Position		Background				Size			Stability		Details and Clearness				Color		Affective Tone			Somatic Ref.		Associative Processes			Temporal Relations		
			Usual	Unusual	Lacking	Color—Shade—Haze	Vague Scene	Clear Scene	Exaggerated	Normal	Dwarfed	Stable	Unstable	Many—Clear	Many—Vague	Few—Clear	Few—Vague	Present	Lacking	Pleasant	Neutral	Unpleasant	Present	Lacking	Present	Lacking	Only Image of Stimulus Word	Recent—Habitual	Recent—Specific	Uncertain
F-Images	A	No.	32	4	4	2	8	22	3	33	....	22	14	26	3	4	3	36	....	26	4	6	23	13	13	23	....	19	13	4
		%	89	11	11	6	22	61	8	92	....	61	39	72	8	11	8	100	....	72	11	17	64	36	36	64	....	53	36	11
	B	No.	35	1	3	2	20	11	....	35	1	14	22	11	5	7	13	33	3	17	19	....	22	14	13	13	10	22	14	....
		%	97	3	8	6	56	31	....	97	3	39	61	31	14	19	36	92	8	47	53	....	61	39	36	36	28	61	39	....
G-Images	A	No.	37	24	12	28	17	4	10	46	5	29	32	19	1	23	18	60	1	27	20	14	7	54	9	52	....	....	....	....
		%	61	39	20	46	28	7	16	75	8	48	52	31	2	38	29	98	2	44	33	23	11	89	15	85	....	....	....	....
	B	No.	4	8	11	....	1	....	....	12	....	2	10	....	1	....	11	12	....	....	12	....	1	11	3	7	2	....	....	....
		%	33	67	92	....	8	....	....	100	....	17	83	....	8	....	92	100	....	....	100	....	8	92	25	58	17	....	....	....
U-Images	A	No.	36	7	12	2	19	10	2	30	11	22	21	26	3	6	8	42	1	27	4	12	6	37	29	14	....	....	....	....
		%	84	16	28	5	44	23	5	70	26	51	49	60	7	14	19	98	2	63	9	28	14	86	67	33	....	....	....	....
	B	No.	3	1	2	....	1	1	....	4	....	2	2	1	2	....	1	3	1	1	3	....	2	2	2	2	....	....	....	....
		%	75	25	50	....	25	25	....	100	....	50	50	25	50	....	25	75	25	25	75	....	50	50	50	50	....	....	....	....

be significant when considered in another connection.[21] Table III shows that it was usually the images of large objects that were under-sized and also those of small objects that were over-sized.

TABLE III

Images of	Exaggerated	Dwarfed
Small objects	10	1
Medium objects	2	..
Large objects	3	16

The small objects which were exaggerated when imaged were a picture of Queen Elizabeth, a pin, a lemon, a key, a cake of soap, a dinner favor, a tomato, a maple leaf, and two flies. The image of a snake was under-sized. The two medium-sized objects which were exaggerated in imagery were a coat and a bag. Of the large objects, a king, a giraffe, and Ceres were exaggerated, while a tower, a valley, a castle, a horse, a temple, a tabernacle, King Arthur, a crusader, a baron, a serf, Marmion, the Delphic oracle, the Nile, and three forest scenes were under-sized when imaged. With 15 of the 17 images that were dwarfed there was a visual background. With 11 of the 15 that were exaggerated there was no visual background or only a shade or haze, while in 2 more cases the scene was vague.

Objects of a certain size are probably perceived with less effort than objects or scenes considerably larger or smaller. Perception of the small objects may involve unpleasant muscular strain resulting from the convergence of the eyes. This is especially true when the object is close to the observer. Large objects or scenes necessitate considerable ocular movement if all the different details are to be clearly perceived. In some cases, images seem to show a tendency to take that size which, in actual perception, would involve the least ocular strain.

Although the three kinds of images did not present marked differences as regards color, stability, and size, certain other peculiarities were more characteristic of one sort of imaged object than of another. We distinguish six cases.

[21] J. M. Baldwin and W. J. Shaw (Memory for square size, *Psychol. Rev.*, ii, 1895, 236) found that the size of comparatively small objects was over-estimated. H. K. Wolfe (Some judgments on the size of familiar objects, *Amer. J. of Psychol.*, 1898, ix, 137) discovered that familiar objects (*e. g.*, bank-notes) were under-estimated when drawn on paper. In criticism of this experiment it has been said that "this fact does not necessarily report the visual image of the note, since reproduction might easily be biased by the introduction of alien senses, *i. e.*, pressure, muscular exertion, etc." (M. Bentley, The memory image and its qualitative fidelity, *Amer. J. of Psychol.*, 1899, xi, 1.)

1. The F-images occupied a "usual" *position* (89% and 97%); the U-images not quite so frequently (84% and 75%). A's G-images were less apt to occupy a usual position (61%), and, in the case of B, the position was even less likely to be usual (33%).

2. The *visual background* in 83% and 87% of the F-images and in 67% and 50% of the U-images was a scene. On the other hand, there were scenic backgrounds in only 35% and 8% of the G-images.

3. The *details* of the images were both many and clear in 72% (A) and 31% (B) of the F's and in 60% (A) and 25% (B) of the U's. The details were few and vague in 29% (A) and 92% (B) of the G-images.

4. *Somatic reference* occurred with 64% and 61% of the F-images, but with only 11% and 8% of the G-images and with 14% and 50% of the U-images.

5. *Associative processes* were present with a considerable number of U-images (67% and 50%), with a smaller number of F-images (36% and 36%), and with still fewer G-images (15% and 25%).

6. As regards *affective tone*, F-images were often accompanied by pleasantness (72% and 47%), U-images were less frequently associated with pleasantness (63% and 25%), while with G-images consciousness was even less often pleasant (44% of A's images) and might be predominantly neutral in tone (100% of B's images). B reported no cases of unpleasant affective tone. Of A's 140 images, 32 were connected with unpleasantness. In 17 of these cases, however, the unpleasantness might be explained by the nature of the object imaged, while in 6 other cases the unpleasant tone is to be referred to associative connections. *Only two images involved a definite feeling of strangeness or unfamiliarity.* One of these was accompanied by pleasantness, the other by unpleasantness. These results would seem to show that images referring to agreeable experiences are more apt to be recalled than are those referring to the disagreeable.[22]

[22] The belief that there is a tendency to forget the disagreeable is held by Colegrove (*Memory*, 1900, 11), Freud (*Zur Psychopathologie des Alltagslebens*, 1907), and Hollingworth (The oblivescence of the disagreeable, *J. of Phil., Psychol.*, etc., 1910, vii, 709). This view is questioned by E. N. Henderson (Do we forget the disagreeable? *ibid.*, 1911, viii, 432), who found that one-third of the memories of ten observers were disagreeable. He considers it possible that the average person actually has more pleasant than disagreeable experiences, and that an incident which is remembered with pleasure might really have involved unpleasantness when it occurred. "We forget not so much disagreeable ideas as useless ideas."

A certain *combination of characteristics* might be regarded as peculiar to the *pure type* of each sort of image. The *pure F-image* may be distinguished by its usual position, its scenic background, many clear details, a pleasant affective tone, somatic reference, and associative processes. The *pure G-image* is in an unusual position and has no background, or merely a shade or haze as background, few and vague details, a neutral affective tone, no somatic reference, and no associative processes. Like the F-image, the *pure U-image* has a usual position, a scenic background, many clear details, a pleasant affective tone, and associative processes; but it has no somatic reference. If, however, one attempts to classify the individual images under these detailed headings, it is evident that there are very few examples of the pure types and many deviations from them.

Table IV summarizes the variations of the images from the pure types. Only 17 of the whole number are "pure" under our definitions, while 48 vary from the "type" in one, and 68 in two particulars. Transition from one class to another was shown in various ways. Let us illustrate. In connection with one image there was a feeling of familiarity, but the observer was unable to place it in any spatial or temporal relations. In other cases there was no recognition, though scenes associatively appeared which the observer thought might possibly have been the original settings of the object. In four cases recognition occurred after the image had begun to fade. Several G-images and one U-image had as backgrounds scenes that were recognized. Once the image remained the same while one scenic background was replaced by another. In 44 cases the pronunciation of the word was

TABLE IV

	A's Images			B's Images		
	F-Im.	G-Im.	U-Im.	F-Im.	G-Im.	U-Im.
Pure type	4	1	7	1	4	0
Variant in 1 characteristic	11	13	10	9	5	..
2 characteristics	14	16	15	19	3	1
3 characteristics	4	15	10	4	..	1
4 characteristics	1	13	1	23	..	2
5 characteristics	1	3	..	..	..	..
6 characteristics	1	..	..	1	..	..

followed by two successive total-images. Of these successions nine were from one G-image to another of the same sort, nine were from an F-image to another F-image, and nine were from a G-image to a representative of the F class. In 13 cases, images from other sense departments were assimilated to the total image. Five of these were temperature-tactual images, 5 were kinaesthetic-tactual, 2 were olfactory and one was auditory.

So far as it is permissible to base general conclusions upon our material, these results seem to indicate that, although visual images may be classified according to their genesis or function, there are no definite groups which show peculiar patternings of the ten characteristics, intrinsic and functional, which we have mentioned. Individual differences are considerable, and intermediate images are very numerous. F-images, G-images, or U-images may, perhaps, best be considered as designating *various points in a developmental or an elaborative series, rather than sharply differentiated classes.*

III. Experimental: Imagery, Ocular Movement and Attention

Experiment 1

Problem and method. The purpose of this experiment was to discover whether there exists any connection between the general character and functions of the visual image and the occurrence and extent of ocular movements. A and B again served as observers. The observer was seated in the dark room with his head fixed in a head-rest. A sheet of blank cardboard was placed at the distance of a meter from his eyes so that a white fixation-point appeared opposite the fovea of the right eye. The experimenter, who was seated at the observer's right, observed the latter's eye through a hand lens. A black box with a very narrow slit in one side was so arranged that the light from an electric bulb inside produced a bright point of light upon the cornea. The position of the box was shifted until the point of light fell upon the iris of O's eye near the edge of the pupil. When the eye shifted, the margin of the pupil moved noticeably nearer to or farther away from the dot of light, which remained approximately stationary. For the practice series, a sheet of black cardboard was used with a horizontal and a vertical line crossing at right angles. Distances of 5 cm were laid off as units along each line. O looked at the fixation-point, then at some point along one of the lines, then again at the fixation-point. After practice, the experimenter was able to tell, with approxi-

mate accuracy, from the appearance of the eye, over how great a distance upon the cardboard the observer's glance had passed in a vertical or a horizontal direction. From the list used in the experiments of Chapter II, we selected the words which had aroused images differing but slightly from the pure types. The selection was made so that the proportion of images in each of the three classes should be approximately the same. Sixty-nine words[23] were pronounced for A, while only the first 35 were used for B. The instructions were those of the preceding experiments with the following additions: "You are to fixate the white dot upon the black screen. When a visual image appears, try to keep it constant, but, if it disappears, do not make an effort to recall it. You are to start the stop-watch when the image first appears, and to stop it when the image finally disappears." After the observer had given his account of the image, he was questioned as to any points which he had overlooked. The experimenter sought complete information concerning (1) the visual background of the imaged object, (2) its size and (3) details, (4) somatic reference, and (5) accompanying kinaesthetic processes.

Results. Table V gives a general tabulation of the images of observers A and B.

Some visual-verbal images occurred, but they are not included in these results. Reports are not included under every heading for every image, since in some cases the image would shift, or O would be uncertain as to an introspective item. The percentages are based upon the numbers tabulated.

As regards the nature of the different sorts of image, these results are, on the whole, in accord with those of the experiments already recorded. F-images and U-images generally had a scenic background, while, with G-images, an imaged visual background was either only a haze or was altogether lacking. In F-images the details were usually numerous and clear. This was less often the case with U-images. G-images were more apt to have few and vague details than were those of either of the other groups. Somatic reference was characteristic of F-images, while it did not seem to be present with the other kinds. In this experiment, U-images seemed

[23] The list of words was as follows: sword, soap, ogre, leaf, ghost, orange, nymph, broom, pin, oracle, cat, tomato, druid, pipe, catacombs, horse, key, hamlet, convent, church, Marmion, lyre, snake, banana, ice, centaur, aeroplane, mirror, child, knife, serf, dungeon, stone, gun, tournament, boat, cloak, river, wagon, nail, tiger, helmet, coin, witch, moat, grave, wand, rose, dog, coat, cloud, ring, lion, grass, lemon, sled, hand, bag, chimney, purse, griffon, temple, shoe, Holy Grail, vase, Jupiter, sultan, shrine, Nile.

TABLE V

		Number of Images	Visual Background				Size			Details				Somatic Ref.		Kinaesthetic Sensations or Images				Ocular Movements	
			Black Screen Only	Lacking	Color—Shade—Haze	Scene	Exaggerated	Normal	Under-Sized	Many—Clear	Many—Vague	Few—Clear	Few—Vague	Present	Lacking	Lacking	Ocular Strain	Other Sensations	Images (Kin.)	Lacking	Present
F-Images	No.	45	0	1	0	44	0	44	1	34	0	4	2	36	7	32	7	1	4	25	20
	%	....	....	2	....	98	...	98	2	85	....	10	5	84	16	73	16	2	9	56	44
G-Images	No.	33	14	10	8	1	0	30	3	13	2	4	12	0	31	25	3	0	0	32	1
	%	....	42	30	24	3	....	91	9	42	6	13	39	....	100	89	11	....	....	97	3
U-Images	No.	18	5	0	0	13	1	11	6	8	4	1	5	0	15	11	4	0	0	6	12
	%	....	28	....	....	72	6	61	33	44	22	5	28	....	100	73	27	....	....	33	66
Total	.....	96	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

the most likely to be exaggerated or dwarfed. This was less often the case with G-images and it seldom occurred with F-images. Ocular movements and sensations of ocular strain seldom occurred in connection with G-images, but were frequently noticed with the other varieties. Table VI shows the number and the extent of ocular movements. Although these

TABLE VI

	Average number of movements per image	Average extent of movement (in cm.)	Right to Left		Left to Right		Up or Down	
			Total No.	Extent	Total No.	Extent	Total No.	Extent
F-images.....	1.84	5.64±2.9	13	4.66	13	7.11	8	3.75
U-images.....	1.33	5.15±2.4	6	3.33	9	6.44	1	2.5

movements were more frequently present with U-images than with F-images, the average number of movements per image was less and the extent was less in the former case than in the latter. "Extent" refers to the distance, as on the cardboard screen, over which the glance of the observer was estimated to have passed, not to the amount of movement of the eye-ball. Complete data concerning the duration of the images cannot be given, since 18 of the 33 G-images were immediately followed by F-images. In such cases, the duration of each could not be accurately determined. In 52 instances, however, the time-interval could be ascertained. These results are shown in Table VII. F-images and U-images were, in general, longer than G-images. The significance of the figures is dubious, however, because of the wide variations in time.

TABLE VII

	Number	Average duration	M. V.
F-images.....	23	24.0 sec.	13.6
G-images.....	35	10.8 sec.	8.1
U-images.....	14	26.8 sec.	12.0

The fact that F-images and U-images are longer than G-images might account in some measure for the occurrence of ocular movements with the two former classes and their absence in other cases. The eyes might tend to move because there was long fixation, regardless of the nature of the accompanying image. The time-interval

could not, however, be the sole factor involved, for ocular movements occurred with some very short F- and U-images, and did not occur with G-images which were considerably longer. Ocular movements occurred toward the end of 6 images which lasted longer than 15 sec., but in 3 cases other movements had also occurred toward the beginning of the period.

The results of this experiment seem to indicate that some relation obtains between ocular movement and different sorts of image. The existence of such a relation may seem strange in view of the results of our earlier experiment, which showed that, when grouped according to characteristics, there are few images of any pure type, each class tending to merge into the others. But the correspondence may be due to the fact that the amount of ocular movement accompanying any visual image is related to its general setting, rather than to the definite patterning of characteristics, which, as we have seen, varies considerably within the groups. It is possible that different characteristic motor attitudes or general conditions of the organism occur with F-images, G-images, and U-images, and that these attitudes involve certain reactions upon the ocular muscles. The fact that kinaesthetic sensations or images were reported in a comparatively small number of cases would not necessarily invalidate such a conclusion. The attention of the observer was directed toward the visual image, and the effects of muscular strain or movement might easily have been overlooked. The experimenter purposely refrained from all unnecessary emphasis upon this aspect of the problem in order that conditions might be as natural as possible.

Experiment 2

Problem and apparatus. It occurred to the writer that the results of Experiment 1 would be more significant if confirmed by investigations involving an objective record of ocular movements. It also seemed advisable to try to find the particular factor or factors which were most closely connected with ocular movement, instead of resting content with the discovery of the association of such movement with certain kinds of imagery. These were our chief purposes in the present experiment. For recording ocular movement, we employed the writing tambour of the laryngeal recorder described by Krueger and Wirth[24] which was connected by rubber tubing to the nystagmograph of A. Schackwitz.[25] A record of the

[24] *Psychol. Stud.*, 1905-06, i, 103.

[25] *Zsch. f. Psychol.*, 1913, lxiii, 442. When the spectacle-frame to which the tambour was attached proved to be unsatisfactory, we removed the tambour and fastened it to a support made of a system of adjustable rods and attached to the head-rest.

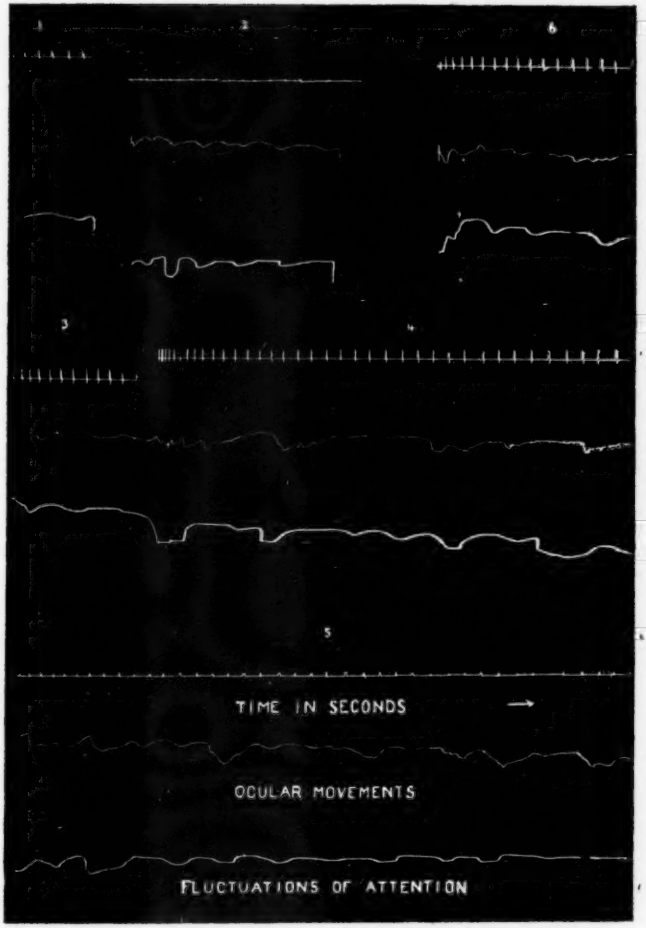
time in seconds was kept by means of an electric marker actuated by a metronome, or, in the later experiments, by a time-clock. A second pneumatic system was used to record the course of the image. For this purpose a rubber bulb was so fitted into a cardboard frame that O could produce variations in the height of the recording line by changing the degree of pressure upon the bulb. Strong pressure meant a high degree of clearness in the imaginal processes.

Method. C, D, and E served as observers. The observer was seated with his eyes closed and his head fixed in a head-rest. The first pneumatic system was inflated, and the small tambour of the second system, adjusted to the head-rest, was placed against the right eye-lid. Movements of the eyes were thus automatically recorded beside the clearness-line upon the kymographic paper. The instructions were as follows: "After a signal 'ready' a word will be pronounced. If a visual image appears, try to hold it constant, but do not recall it when it disappears. With the right hand, compress the bulb when the image appears. Increase the pressure whenever the image grows clearer and diminish the pressure whenever the image becomes less clear. After the image has disappeared, you will be interrogated as to (1) shifts in attention from object to object, (2) changes in the clearness, the intensity, and the content of the imaginal object, (3) associative processes, (4) somatic reference, (5) the visual background of the image, (6) specificity of the imaged object and its temporal and spatial relations, and (7) familiarity." Sixty-three words were used with each of the three observers.[26]

Results. Nothing of importance resulted from this experiment in respect to the characteristics of the different sorts of images. The descriptions are in general accord with the more detailed accounts discussed above. The results are significant, however, in that they show an appreciable correspondence between fluctuations in the clearness of the imagery and ocular movements. The records were divided into 5 classes according to the degree of correspondence. We described a record as showing no correspondence when one line fluctuated and the other did not, or when there were striking differences in the number and the position of fluctuations. Figure 1 shows typical examples of the records in which there was correspondence. Records 1, 2, and 3 are samples of high correspondence, record 4 of close correspondence, while in 5

[26] Some of the words were as follows: pickle, wizard, maypole, shell, moat, Hercules, shepherd, thimble, rainbow, scythe, commencement, dell, note-book, Scotchman, Cinderella, mouse.

Fig. 1


TIME IN SECONDS
OCULAR MOVEMENTS
FLUCTUATIONS OF ATTENTION

the resemblance of the lines is general, and in record 6 the correspondence is limited. Table VIII shows the classification of the results for each observer.

TABLE VIII

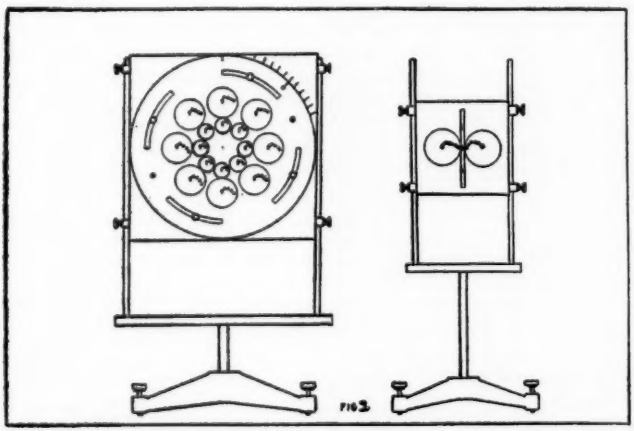
	Amount of Correspondence					
	None	Some	General	Close	High	Totals
C	17	8	24	6	10	65
D	17	21	9	5	8	60
E	10	19	7	7	4	47
Totals	44	48	40	18	22	172
				128		

In 128 of the 172 cases, there appeared, then, a correspondence between the records for fluctuations of the clearness of the image and the records for ocular movements. This agreement is the more striking in view of the fact that very slight variations in the adjustment of the apparatus or in the time of O's response in varying the pressure upon the recording bulb might have changed the records in such a way that a correspondence which really existed would have been obscured.

Experiment 3

Problem and apparatus. In all of the preceding investigations, the images evoked differed widely in their nature and in their origin. Some were very schematic, while others presented many specifying details. A considerable number referred to recent experiences, but some were related to habitual perceptions, and still others symbolized classes of objects. In view of these facts, it seemed advisable to investigate the occurrence of ocular movement in connection with images resulting from similar perceptions. We decided to employ a series of objects which were homogeneous except in respect to meaning, and to note whatever differences in ocular movement might occur when the objects were imaged. For this purpose, we devised a series of thirty sense and nonsense figures. Each figure or diagram was cut from white paper and pasted on a black card 5 inches square. Half of the pictures represented meaningful objects, while the others were intended to be meaningless.

Ocular movements were detected by a method different from the methods used in our previous investigations. In Experiment 1, changes in the position of the eye had been observed by the experimenter; in Experiment 2, a mechanical device had been employed. In the following series, the observer himself reported the occurrence of ocular movement. Our plan was to place before the observer a set of points of light arranged in such a way that, when fixation was steady, all of the lights would fall upon the blind-spot. A slight movement of the eye, however, would bring some of the bright points within the field of vision.[27] The apparatus (represented in Figure 2) consisted of two black metal light-boxes designed for the investigation of indirect vision. The smaller light-box supplied the fixation-light and the larger box the lights for determining the limits of the blind-spot. Rotating discs upon the face of the larger box provided for a radial series of light-spots, 5 mm apart, along any one of 360 diameters.



Method. C, D, and F served as observers. The observer was seated in a chair with his head fixed in a head-rest and his right eye covered with a black cloth. His left eye was at a distance of 1½ meters from the face of the small box,

[27] Perky (*op. cit.*, 437) employed a similar method. Our arrangement provides for the detection of considerably smaller movements of the eyes and also for a nice control of the position and intensity of the light-spots.

and the point of light at the intersection of the two lines of holes appeared opposite the fovea. This dot served as a fixation-point; the other openings were covered. Light was admitted through apertures successively nearer to the center of the face of the large light-box until those points were found which cast beams of light just within the area of the blind-spot. As a check upon the accuracy of the adjustment, the slide and the disc on the small box were so moved as to admit light through apertures 5 mm above or below, and at the right or the left of the original fixation-point. When either of these four adjacent spots was fixated, some of the points of light on the large box became visible. An extremely slight change in the position of the eye, then, brought the lights partially within the field of vision.

Before each experiment, the head-rest and the boxes were adjusted with reference to O's blind-spot, since a different arrangement was necessary for each observer. When O had taken his place in the dark room, he was given the following instructions: "You will be shown a series of four drawings, the experimenter naming each one as it appears.[28] Shortly after a 'ready' signal, a drawing will be exposed for 20 seconds. After a further interval, of 20 seconds, another will be exposed, and so on." The drawings were placed over the fixation-point of the small box and were illuminated from above. During this part of the experiment, the apparatus was concealed by a black screen with an opening (2″ x 1½″) through which the card was visible. After the perceptual series, the observer was instructed as follows: "You are to fixate the single point of light. The experimenter will pronounce the names of the drawings, and you are to call up a visual image of each. Try to hold the image constant, but, if it disappears, make no effort to recall it. Press the key when the image appears and release and press it whenever the lights at the side become visible. Release the key and say 'now' when the image disappears. Then give complete introspections for the period of the image." A kymographic record was made showing the appearance and disappearance of the lights as indicated by O. The experimenter timed each image with a stop-watch. During the last half of the series, each record was made for a period of 20 seconds, and the observer was required to recall the image if it disappeared during that time. Several other records were made as con-

[28] The following names were given to the figures: wij, bottle, ked, butterfly, fak, turtle, ged, star, pam, spool, tis, daisy, rel, key, bam, fish, hof, ring, lat, apple, zum, leaf, doj, cup, mej, knife, dak, pipe, kif, scissors.

trols with each observer. Under the controls, O was told to fixate the point of light until the experimenter gave a signal to stop at the end of 20 seconds. Under these conditions, no attempt was made to arouse imagery. After each experimental period O's descriptions were transcribed from his dictation. When necessary, the experimenter questioned him with respect to (1) the kinds of conscious processes integrated with the total visual image, (2) associative processes, (3) the clearness of the image, and (4) the accompanying affective tone. O was then asked to sketch the object as perceived and also as imaged.

Results. Although the drawings did not serve the purpose for which they were primarily intended, the results were significant in other respects. Most of the pictures devised for nonsense drawings either proved to be meaningful or were accompanied by meaningful associative processes. Only 7 of the 88 images had no meaning for the observer or signified simply "drawings-shown-a-few-minutes-ago." There was no appreciable correspondence between images of this sort and the presence or absence of ocular movement. The experiments did, however, supplement the results of the investigations which were mentioned in Section II with respect to the *size* and the accompanying *affective tone* of the image.

We have already cited a possible objection to the observer's reproduction of the image by a drawing. Since kinaesthetic and tactual sensations were involved in such a depiction, it was possible that the results were not exact representations of the images. But even if allowances are made for constant errors, the total results seem significant.

Since the drawings were 1½ meters away, we might expect the observer's representations to be slightly smaller than the originals. There was, however, a strong tendency, with two observers, to exaggeration in the image. No drawing was smaller than the figure by more than an inch, while 7 exaggerated it by 1-6 inches.

All observers reported a predominance of pleasantness over unpleasantness in the images (43:19). As a rule, however, the affective tone was connected with the free or impeded fulfillment of instructions, not with the character or the significance of the total images. Too often writers have assumed without warrant that coincident affective tone and image were inherently related.

The correspondence between *ocular movement, the sort of image,* and *the condition of attention* appears when we compare all the results obtained from the three observers. The num-

ber of images associated with ocular movements is shown in Table IX, and the duration of these movements with any

TABLE IX

Observer	C.		D.		F.	
	I.	Co.	I.	Co.	I.	Co.
Ocular movement	29	4	7	4	28	3
No ocular movement	0	0	23	1	1	0

image, in Table X. (I. stands for the period of the image; Co., for that of the control). Not only did D have fewer images accompanied by ocular movement than did C or F,

TABLE X

DURATION OF OCULAR MOVEMENT

Seconds		2	3	4	5	6	7	8	9	10	11	13	15	20
D	I.	..	..	1	..	..	2	1	..	..	..	..	..	3
	Co.	..	..	..	..	..	..	..	..	..	..	..	1	3
C	I.	1	5	4	4	2	8	2	..	2	..	..	..	1
	Co.	..	..	1	2	..	1	..	..	..	..	..	..	..
F	I.	1	..	3	1	2	7	1	2	4	1	2	..	4
	Co.	..	1	..	..	..	1	..	..	1	..	..	..	..

but the number of movements with a given image was apt to be less in his case. There was also a noticeable difference in the general *character of the images* of the three observers.

(1) The *size* of D's images, according to his drawings, varied but slightly from that of the diagrams, while both C's and F's images were exaggerated in approximately 68% of the cases.

(2) None of D's images were *incomplete*, but 11 of C's and 15 of F's lacked some or many details.

(3) Four of D's images, 8 of C's and 9 of F's revealed *inaccuracies* of detail.

(4) Three of C's images and 6 of F's were of *objects other than the diagrams*. Four times, in the case of F, these representations were incomplete. D was always able to arouse an image of the perceived drawing.

(5) D's total images never contained imaginal visual elements which were not represented in the corresponding perceptual objects. No processes from other sense departments were intimately integrated with the images. Such integration occurred with 5 of C's images. Four times the added elements were visual, and once they were kinaesthetic.

In 14 instances, F's total images were *elaborations of the perceptual object.* The added elements were visual in 3 cases, kinaesthetic in 8, tactual in 2, and organic in one.

(6) D always drew the same diagram as representing both the image and its corresponding percept. This was the case with only 11 of C's images and with none of F's.

Individual differences were noticeable, not only in the character of the image, but also in the *state of attention.*

(1) In the case of 22 of D's images, there were a few (from one to three) simple groups of associative processes, usually secondary (verbal). Twelve of C's images and 19 of F's either lacked such processes or were accompanied by a great many. Attention was apt to fluctuate when associative processes were so numerous as to act as distractions or when the absence of these processes made the images uninteresting.

(2) Further differences existed with respect to the degree of clearness and its fluctuations. Over half of D's images were very clear and steady. Twenty of C's images were very clear, but 19 of them fluctuated. Moderate clearness was characteristic of 15 of F's images, and fluctuations occurred in 24 cases.

(3) D's attention was less frequently secondary (or active) than was C's or F's. D reported a conflict between groups of processes, or attention with effort, 6 times, C 11 times, and F in 9 cases.

In brief, *fixation was usually steady* when an image was very *clear* and *did not fluctuate,* when it was accompanied by *few associative processes,* and when *attention was without effort.* Under other conditions ocular movement tended to occur.

The dissimilarities among the images of a single observer are associated with ocular movement in the same way as are variations in all the images of different observers.

In the six cases in which D's attention was secondary, fixation was unsteady. During the course of 4 other images the eyes moved, although attention was without effort, but in all of these instances there were many associative processes or irrelevant ideas. The one image which was noticeably vaguer than any of the others was also accompanied by ocular movement. All of C's images were accompanied by movements of the eyes, but the one image with which there was only a single movement in 20 seconds was very clear and constant, and attention was without effort. One of F's images was accompanied by no ocular movement. Attention was without effort, and the image was clear and constant. With 4 of his other images, there was only one movement in 20 seconds. In all of these cases, attention was without effort. Two images were very clear, and the other 2 were moderately clear, while the images remained constant or fluctuated but slightly.

If we turn to the kymographic records of the control-experiments, we see that they are in accord with the results already mentioned. Ocular movement frequently occurred during the controls, and, when it did, the general conditions of consciousness closely resembled those which were characteristic of the images accompanied by ocular movement.

To sum up, we may say that there is usually no movement of the eyes with images which are fairly faithful representations of the corresponding perceptual objects; while ocular movement tends to occur with images which differ from the perceptual objects in size, and in completeness and accuracy of detail, and, in some cases, when processes from other sense departments are integrated with the images. Moreover, fixation is apt to be steady when there are few associative processes (but not so many as to distract attention from the image and not so few as to allow attention to wander), when the image is clear and stable, and when attention is without effort. When these conditions do not exist, ocular movements tend to occur.

The results of Experiment 3 are in general accord with those of a preliminary series in which C alone served as observer. The apparatus was a rough wood and cardboard model like the metal boxes in all essential details. A series of words was used to arouse images. O was required to time the images with a stop-watch and to press a recording key whenever the points of light became visible. During the course of 15 of the images, a beam of light was thrown upon the cornea of O's eye as in Experiment 1. Unfortunately, the light had to be of such a low intensity that the experimenter's observations of ocular movement are not reliable. The experimental conditions, especially the presence of the beam of light, distracted the observer. For this reason, the value of the results might be questioned if they were not in agreement with those of the other series.

Records of 22 images were obtained. Two of these were U-images, 13 were G-images, 7 were F-images. Of the F-images, 6 had somatic reference, 5 had a recognized scenic background, and 3 had fairly many associations. Of the G-images, none had a scenic background, and 11 had few or no associations. Ocular movements were reported by the observer with 5 (71%) of the F-images and with 7 (54%) of the G-images.

As regards attention to the image, there was no ocular movement in the one case in which the image was very clear and constant, or with another image which showed a gradual decrease in clearness. Ocular movement occurred 1, 2, or 3 times in 5 of the 10 cases in which the image was vague but exhibited no appreciable shifts in clearness, and in 8 of the 10 cases in which there were marked fluctuations in the clearness of the image. There was evidently a degree of correspondence between the frequency of ocular movement and the kind of image, and a rather marked relation of ocular movement to attention.

Experiment 4

Problem and method. While Experiment 3 was in progress, it occurred to the writer that, in spite of the apparent accuracy of the apparatus, the observer might sometimes be unaware of the spots of light even when the eyes moved. If O's attention were focused upon the visual image, there was a possibility that the light might fall upon a sensitive portion of the

retina without touching off a report. To test this hypothesis, we combined the methods of Exps. 2 and 3. With the left eye, the observer fixated the single point of light as in the preceding investigation. The right eye was closed, and the tambour used in Exp. 2 was adjusted against the lid. In general, the procedure was the same as in Exp. 3, except that, instead of exposing the drawings in a perceptual series and later arousing the corresponding images, a number of words were used as in Experiment 2. C, D, and F again served as observers. As a preliminary control, before each record was made, the observer intentionally moved his eyes. In all of these cases the movement was recorded and the dots of light became visible. Each record was taken for a period of 20 seconds, as in the latter part of Exp. 3.

Results. Six records were made with D as observer, 5 with F, and 8 with C. In D's case, no ocular movement was detected by either method. The dots were never visible during the 20 seconds of fixation, and the record made by the pneumatic system showed no fluctuation. During the course of 4 of F's 5 images, dots became visible, but the other recording line did not waver. Very slight ocular movements evidently sufficed to bring the dots within the field of vision, but were not large enough to affect the tambour. One of C's records indicated that the dots became visible 5 times while there were no corresponding fluctuations in the other line. In the other 7 cases, ocular movement was indicated by both lines. There was a general conformity between the two records, although in some cases the record made by the pneumatic system indicated more fluctuations than the other line.

There are several possible explanations of these apparent inconsistencies. (1) C sometimes saw the points of light 8 or 10 times in 20 seconds. It is very likely that she did not react quickly enough to record all the changes. (2) A twitching of the right lid might have changed the one record, although the eyes themselves remained steady, so that no dots appeared. (3) Where the excursion of the eyes was fairly wide, a fluctuation in the pneumatic record might have occurred when the projection of the cornea crossed the bulge of the tambour, and again when the eye resumed its original position, although the dots were visible but once. While one record was being made, the electric current was accidentally reduced, and the points of light became very faint. It was probably due to this fact that the dots were visible less often than in the previous periods.

The results of this experiment seem to indicate that the suggested hypothesis is incorrect. If O's eyes had moved while he failed to notice the points of light, the pneumatic record would have fluctuated, while the other was unaffected. But this was not the case. When movement was recorded

by only one line, it was the record made by O that showed fluctuations. The pneumatic system seemed the less accurate of the two. When slight movements of the eyes occurred, the observer noticed the dots, but the tambour was apparently not affected, while larger movements were recorded by both systems.

From the results of Exp. 4 we infer that the perception of the dots of light during the experimental period indicated actual movement of the eyes. The results of the short trial preliminary to Exp. 3 revealed the same correspondence between F-images and G-images which was discovered in Exp. 1. Ocular movement usually occurred with the former images, but not with the latter. In Exp. 3, we found that the amount of resemblance among imaged objects and the corresponding perceived objects seemed to be connected with ocular movement. As has already been suggested, this correspondence may reasonably be referred to an association of ocular movements with certain conditions of attention. Both Exp. 3 and the preliminary trial confirm the correspondence of ocular movements with the degree of clearness and fluctuations of attention which was the most significant discovery in Exp. 2. In Exps. 1 and 2, the arousal of a particular image was not required, and the experimental conditions did not seem to impose any tax upon the observers' ability to hold the attention steady. In Exp. 3, however, there occurred, as a result of the exacting instructions, numerous cases of secondary attention. There proved to be a positive correspondence between this sort of attention and ocular movements.

Were we to attempt an explanation of the correspondence which we have discovered between different sorts of image, attention, and ocular movement, we should turn naturally to the facts of perception. A series of special experiments would be necessary fully to substantiate a transfer of general motor attitude or of ocular movement from perception to visual imagery. Our results suggest, however, that there are several possible likenesses among perceptions and images in respect to movements of the eyes.

(1) When an extended perceptual object close at hand has many details, we must, in order to gain an accurate impression of it, glance now at one portion, now at another. In a similar way, we have frequently discovered ocular movement and shifts of attention where an imaged object is rich in detail or is accompanied by numerous associative processes (as was the case with many of the F-images and with some of the images of drawn figures in Exp. 3).

(2) When a perceptual object has very few details, we are apt to grasp its significance at a glance and then to turn our gaze and our attention to something else. A similar tendency was manifested, in our experiments, in the case of some uninterestingly simple images.

(3) In perception, when an object lacks cognitive clearness, our eyes are often focused first on one part, then on another, in order to gain a more definite impression. Such waverings of the glance were also characteristic of images.

(4) Under normal conditions, when we attend successively to different aspects of a perceptual object, our glance almost invariably follows the direction of our attention. We have already given instances of the agreement between fluctuations of clearness and shifts of fixation in imagery.

(5) Finally, when two rival objects claim the perceptual attention, the glance is apt to waver between them. Our results showed that secondary attention to imagery also involved ocular movements. All of these resemblances seem to point in the same direction. In the absence of contradictory evidence we may, then, reasonably suppose that the relations existing between the character of the object, attention, and ocular movements in perception are transferred to analogous cases of imagery. Such an hypothesis is in harmony with the current view of the physiological functions underlying perception and imagery. When an object formerly perceived is imaged there occurs, presumably, through central excitation, a reinstatement of the approximate physiological conditions of perception. The imaged object presents much the same color, shape, size, and details as does the perceptual object. There might easily be a similar reinstatement of muscular innervations. In fact, the recurrence in imagery of the movements of the eyes involved in perception is a more probable phenomenon than is the accurate repetition of the visual details of the perceived object, since ocular reactions which are alike (at least in their gross characteristics) occur with a large number of perceptions, while a comparatively small number of objects present a close resemblance in their qualitative aspects. That is to say, there may be more likelihood of the integration of generic muscular reactions in imagery than of the formation of generic visual images.

IV. Summary and Conclusions

The results upon which we base our conclusions were obtained from six trained observers, four of whom served in two or more of the four principal experiments. The ocular

movement occurring in connection with visual images was recorded in the various investigations by three different methods. There was a general agreement in the results whenever two or more experiments involved the same problems. Although individual differences were sometimes conspicuous, they were of such a sort as to substantiate our conclusions, not to invalidate them.

Agreement between our results and those of other investigators is as close as we could reasonably expect in view of the differences which obtain in instruction and method, and, especially, of the differences in the criteria used for classifying images. (See Table XI). The "memorial image" of

TABLE XI

	Specific Reference		Generic Reference
Clark	F-Images	U-Images	G-Images
Perky	Memory (part. and pers. ref.)		Imagination
Ogden	Memory (fam.?)	Imagination	
Koffka	Individual (degrees of ind'ing and loc'ing)	Individual	General (in part)

both Ogden and Perky should probably be considered as a sub-class of our F-images. Perky's images of imagination we should generally have classed—so far as we can tell from her descriptions—as G-images; Ogden's images of imagination,[29] as U-images. We found that our G-images (Perky's imaginations)[30] and our U-images (Ogden's imaginations) were usually unlike in most of their characteristics. It is not strange, then, that there should be considerable disagreement between Perky's and Ogden's results when these two classes are compared. Koffka's general images would coincide in part with the G-images of our classification, while his individual images would include both our F and U classes.

1. Five of the characteristics of images which we have examined were also considered in much the same way by

[29] Ogden appears to have left his observers free to apply their own criteria to their images: he says, "The criteria which seemed to be employed primarily by our observers were those of 'familiarity' and 'unfamiliarity'" (p. 384).

[30] Perky writes of "generic images" and of "habitual imaginations" (pp. 440, 447) in contrast to "particular images."

Perky, Martin, and Ogden. The following summary gives a comparison of the results.

(a) There was a general agreement in respect to *associative processes,* which frequently accompanied the memorial images of Perky,[31] Martin,[32] and Ogden,[33] and were found with our F-images, and also with Ogden's images of imagination and our corresponding U-images. With Perky's[34] and Martin's[35] images of imagination and with our corresponding G-images these accompanying processes occurred less often.

(b) Three of the four investigations indicated similarities of *clearness* and of *detail.* The memorial images of Ogden[36] and of Martin,[37] and our F-images, were apt to be distinct, not "scrappy" and "filmy," as were Perky's. Instead of being "substantial" and "complete," as were Perky's images of imagination,[38] our corresponding G-images often presented few and vague details. Many of Ogden's images of imagination[39] and of our U-images were detailed and clear.

(c) The results of Ogden[40] and of Martin[41] also agree with ours in failing to show any correspondence between the kind of image and the presence or absence of *color.* Perky gives no statistical summary, but describes the images of memory as "colorless etchings," and those of imagination as "oftentimes, on the contrary, very highly colored."[42] Her statements, however, appear to be contradictory, for she also states that the images of memory "retained their daylight character," while those of imagination took the illumination of their surroundings.[43] This statement might be interpreted as meaning that it was the memories that were colored and the imaginations that had no color of their own.

(d) The results of Ogden's investigation and of our own do not agree with Perky's with respect to *affective tone.* Ogden[44] found no evidence of Perky's memorial "mood of recognition" or imaginative "mood of surprise." In our investigation, the images (especially in the F class) were frequently pleasant, but an explicit feeling of familiarity was not always found with F-images, and a feeling of strangeness or surprise occurred with only two U-images.

(e) As regards *stability,* there is no correspondence of results. Perky's memorial images were described as "scrappy and fleeting,"[45] her images of imagination as "substantial."[46]

[31] Perky, p. 451. [32] Martin, p. 408, 412. [33] Ogden, p. 405.
[34] Perky, p. 450. [35] Martin, p. 408, 412. [36] Ogden, p. 398.
[37] Martin, p. 400. [38] Perky, p. 451. [39] Ogden, p. 398.
[40] Ogden, p. 396. [41] Martin, p. 405. [42] Perky, p. 447.
[43] Perky, p. 446. [44] Ogden, p. 398. [45] Perky, p. 447.
[46] Perky, p. 451.

Martin's images of memory were usually, though not always, more stable than those of imagination;[47] and Ogden found about the same number of stable images of his two kinds.[48] Our investigation revealed no significant correspondence between the kind of image and its stability. Where a comparison is possible, the total results of Ogden and Martin agree, in general, with those of the writer, while all of these three investigations give evidence which is contradictory to that of Perky.

2. As regards *ocular movements*, our results agree with Perky's in so far as these movements usually occurred with her images of memory and frequently with our larger class of F-images, but were not, as a rule, reported with her images of "imagination" or with our corresponding G-images. The frequent occurrence of movement with our U-images, however, suggests that no essential relation obtains between images of "memory," as contrasted with other forms or functions of imagery, and these kinaesthetic processes. That is to say, the conditions of ocular movement with imagery seem to be *general* conditions,—not the conditions which distinguish two imaginal functions, memorial and imaginative. Indeed, it is doubtful whether it is feasible and proper to attempt to oppose these two functions at the level of the total image. Our own analyses, as well as those of Koffka, suggest, instead, a very large number of functional gradations for the simpler imaginal complexes;—gradations of specifying, of individualizing, of generalizing, of symbolizing, and of reference to the observer, to objects, to times, to places, and to contexts. The alleged functional distinctions based upon "particularity" and "personal reference" are gross, and, moreover, we are not persuaded by the facts that they are correlated with such differences in process and integration as temporal course, clearness, substantialness, and affective and organic accompaniments. As for the presence and absence of ocular movements under imagery, we are not certain that familiarity, "the mood of memory" (Perky, p. 451), is essentially connected with this special kinaesthesis; while we have failed to discover by introspection an antithetical or contrasted mood of unfamiliarity or "novelty" to mark the absence of such movements. These specialized movements we are inclined to account for in another way. They seem to us to be symptomatic of those general central conditions which underlie *determination* and which fix the state and the configuration of conscious-

[47] Martin, p. 407. [48] Ogden, p. 404.

ness,—*i. e.*, fix attention and associative completion.[49] Whenever these general conditions approximate or tend to reproduce the usual psychophysical accompaniments of visual perception, then the ocular movements also tend to occur. Visual perceptions normally flow in trains, passing from feature to feature of the object and likewise from object to object. The kaleidoscopic change of clear processes bears with it a succession of ocular movements. We believe that whenever this diffusive and exploratory kind of visual attention occurs, whether or not the organism is immediately affected by a visual stimulus, there normally appear, save under some special inhibition, the small movements of the eyes which have now been detected in many experiments set for the study of imagery.

If our view is correct, then the presence and frequency of ocular movements would have no immediate or intrinsic connection either with familiarity or with "personal reference" and "particularity;" though it might well be true that those images which make most explicit reference to the observer and to his past experiences also most frequently fulfill the general conditions just referred to.[50] It follows that isolated, detached, unset and un-detailed objects, such as appeared in our G-images, would least reinstate the usual conditions of perception; but it does not follow that these objects furnish the materials of "imagination." We are thus led to connect ocular movements more directly with general central and conscious conditions than with special functional differences displayed by the image.

In so far as it is permissible to base generalizations upon our experimental results, we feel justified in drawing the following conclusions:

1. If visual images are divided into three groups upon the basis of the presence or the absence of (1) specific reference and (2) familiarity of the object, certain other functional characteristics are found to be rather closely associated with a particular group or with groups of images. Pure types, however, are comparatively rare, and intermediate forms are relatively numerous.

2. A correspondence discoverable between kind of image

[49] Perky found that attention wandered in memory but was narrowly focused in imagination (p. 449).

[50] As regards audition, olfaction, and the other senses, the facts are not sufficient to warrant general conclusions. Remembering the history of the doctrine of "fluctuations of attention," the author is suspicious of any general functional difference which does not take into account the bearing of sensory adjustments.

and amount of ocular movement is probably to be referred to certain general conditions of attention.

3. Changes in the clearness of the image correspond, to an appreciable extent, to movements of the eyes.

4. Ocular movement is more likely to occur in secondary attention than in primary or derived primary attention.

5. Characteristic ocular movements, and possibly general motor attitudes, seem to be transferred from visual perceptions to visual imagery.

RECONSTRUCTIVE RECALL*

By Garry C. Myers and Caroline E. Myers, Brooklyn

It is common observation that if one fails in an attempt to recall a bit of one time familiar experience, later one may recall numerous remnants of it, and may reproduce the greater part or even all of that experience.

With a purpose to estimate how far one can recall what seems to have been forgotten, and to determine some of the conditions under which the forgotten can be reconstructed the following study has been undertaken.

The six subjects were instructed to try to reconstruct from memory, one or more selections, which they once readily could quote, but which in the meantime, they almost completely had forgotten. They were told to make their attempts at recall at regular intervals or at the most convenient time. They were asked to introspect and were urged especially to note as far as possible the conditions under which the recalls were made. Some worked at several selections over the same period of time. Others worked upon only one at a time, and, when they had given that up in despair they turned to another selection. The period of time over which the subjects worked varied from a few weeks to several months.

One subject recalled at regular intervals; she carefully noted her time for recall which was generally ten minutes. The other five were irregular in intervals, and length of recall times, and one of these merely indicated the order of the recalls without regard to the time when they were made. Two subjects, G. M. and C. M., made several recalls in a day and they spent from 5 minutes to an hour at recalls. Only three indicated the interval between learning and recall. There could hardly be an absolute certainty as to the absence of recalls during these intervals. One subject, G. W., was certain she had no recalls of one selection while she stated she had many recalls of another selection, during the interval.

Since not all the materials readily admit of statistical analysis some typical records will be quoted and some of their prominent characteristics will be pointed out.

* Reported, in brief, at the November (1915) meeting of the New York Branch of the American Psychological Association.

The following from Lincoln's Gettysburg Address was given by Miss T.

'Four score and twenty? years ago our fathers brought forth on this continent a new nation conceived in liberty and dedicated to the proposition that all men are created equal. We are met on a great battle field of that nation. We have come to dedicate a portion of that field as a final resting place for those who here gave their lives that that nation might live.'

Note—"I also remembered part of the last phrase—'of the people, by the people and for the people.'

The question mark after *twenty* means that my common sense told me it could not be *twenty*, altho I wrote that number and could not remember the right one. I started the test January 26, 1915, and took twenty minutes every morning for the experiment."

January 27th. "I remember that somewhere near the middle of the address there were the words 'above our power;' that some people said 'our poor power,' but I knew I had been told that 'poor' should not be there."

January 28 to January 31 "I added no new words."

February 1. "While playing the piano and being seemingly very interested in a new piece I was trying, I suddenly found myself saying, 'The world will little note nor long remember what we say here but it can never forget what they did here.'"

February 2. "When I opened to the first page of a book I just got from the library I saw written 'To J. R. D. I dedicate this book.' The word *dedicate* seemed to remain with me and even at dinner I found myself saying it. Then when I started to think of the selection I remembered that part of it went thus: 'But (?) —— we cannot dedicate we cannot consecrate we cannot —— this ground.'"

February 3. "In the morning when my mind was on the experiment and I deliberately tried to remember more of it I got only the very last few words, 'shall not perish from the earth.'"

February 4, 5, 6. "No new words. On the 5th in talking to a friend H. B. about another individual X, H. B. said she thought X should carry on the noble work which her mother (X's mother) had been striving so hard to finish. I suddenly remembered that that idea was expressed in the Gettysburg Address somewhat this way: 'It is for us the living to carry on the unfinished work which those who fought here have —— so —— advanced."

February 7. "In the evening I sat down and tried to say the address right off and thus got some new words. After a few attempts, probably 6 or 7, I found I had picked up two new words. In the sentence 'But we cannot consecrate we cannot dedicate we cannot hallow this ground. *Hallow* was a new word. I went on and finally got a good deal more as follows: 'The brave men living and dead, who struggled here have consecrated it far above our power to add or detract.' The words 'above our power to add' I had had before.

"I also got the rest of the sentence of February 5th as follows: 'It is for us the living rather to be dedicated here to the unfinished work which they who fought here have thus far so nobly advanced.'"

February 8. "In the assembly hall to my regret the pupils said the Gettysburg Address. ——.

"My test of remembering this speech brought up many facts, ideas and people that I had forgotten since my elementary school days."

Subject G. W., after an interval of nine years, recalled, in 16 trials over 13 days, 65 per cent of the "Wreck of the Hesperus." Of this, 44 per cent was added after the first recall. Variations and confusions were very pronounced. "For a long time," she wrote, "the first verse seemed to be,

'It was the schooner Hesperus,
That had sailed the wintry sea!'
'By the long gray beard and glittering eyes,
Now wherefor stoppest thou me?'

"These last two lines from the Ancient Mariner would persist in preventing my progress."

Of her fifth and sixth trials she wrote: "Badly mixed up with Ancient Mariner."

Confusions within the poem were frequent. For example, of the stanza,

"He wrapped her warm in his seaman's coat,
Against the stinging blast;
He cut a rope from a broken spar,
And bound her to the mast."

she recalled in the third trial, *rough* for *seaman's; lashed* for *bound* and omitted *stinging,* and *broken spar.* She placed the fourth line for the second. Five days later she got *stinging blast,* but could not place it until the final reconstruction, after six more days. This delay in proper placing till the final recall was quite frequent for G. W., as well as for some of the other subjects. In her final recall she interchanged the third and fourth lines of stanzas XI and XII, respectively, whereas in her first recall they were correctly placed. Likewise in her third trial she crossed out a half line of a stanza and substituted a wrong phrase, but corrected it in the final recall. Both stanzas XV and XXII have as rhyming words, *snow* and *Norman's woe.* When, however, she recalled *driven snow* where she should have *carded wool,* in stanza XVIII, she immediately gave *Norman's woe* as the rhyming word. Space does not admit of her many other substitutions, confusions, doubtful factors, and omissions.

The same subject added 33 per cent of the Psalm of Life in 8 subsequent recalls. In her first recall of stanza IV she got line 1 and 4, but could get none of line 2. She thought however, that line 3 ended in *heart is beating.* This really is the gist of lines 2 and 3:

"And our hearts though stout and brave,
Still like muffled drums are beating."

On the evening of the same day she recalled the whole stanza correctly.

Subject G. M. added 44 per cent in four subsequent recalls of the same poem. In his fourth trial he recalled: "Art is long and time is fleeting" and "funeral marches to the grave," but did not know that they belonged to the same stanza. Later in the same day he got:

"—— —— —— —— drum beat
Funeral marches to the grave."

Then he recalled:

"Art is long and time is fleeting,
And our hearts though stout and brave."

"When this was written," he noted, "I got *drum beat* for the end of the third line; then *Still like* came up, then *drum beating*, then came *muffled drums* and all at once,

"Still like muffled drums are beating
Funeral marches to the grave."

For him the following lines from "The Present Crisis" frequently obtruded but were seldom accepted as true:

"We ourselves would pilgrims be
Launch our Mayflower and steer boldly
In the desperate winter sea."

WOODMAN, SPARE THAT TREE

Recalled by Miss M. S.

No. 1.

I

1st Trial. Woodman, spare that tree! Touch not a single bough;
In youth it sheltered me and I'll protect it now;
2d Trial. 'Twas my forefather's hand that placed it near his cot
There, woodman, let it stand, thy axe shall harm it not!

Note—"In the 2d trial the last line of the stanza came to me before the third line. I kept repeating the first two lines over and over again trying to remember some more. I remembered a movement of my hand that I had been taught when I said, 'There,' this gave me a cue to the last line. I tried to find a word that rhymed with 'not.' When I thought of 'cot' I remembered the rest of the line."

No. 2.

II

8th Trial. That old familiar tree, its glory and renown
7th Trial. Are spread o'er land and sea, and would'st thou hew it down?
3rd Trial. Woodman forbear thy stroke! Cut not its earth-bound ties;
5th and 6th Trial. Oh! spare that aged oak now towering to the skies.

Note—"Some one asked me what I was trying to remember; when I told them they said 'That old familiar thing; anyone could remember that,' then I got the first line of the stanza."

"I was listening to a speaker who said 'The blood of our best men is spread o'er land and sea,' and involuntarily I supplied, 'and would'st thou hew it down.' Try as I would I could get no more."

"I recalled that when I was learning the poem I had been told to say it as though I were entreating some one then I remembered the third line but could not place it in the poem."

"In this trial a friend who had heard me reciting some of the poem and was impatient for me to join her shouted, 'For goodness sake spare many and come on,' then I thought of the first half of line four."

"When I repeated the poem I remembered that—'Oh! spare that aged oak' came after line 3, stanza II. When I said the two together I got the rest of the fourth line."

No. 3.

III

8th Trial. When but an idle boy I sought its grateful shade
10th Trial. In all their gushing joy, here too my sisters played;

4th Trial. My mother kissed me here; my father pressed my hand,
1st Trial. Forgive this foolish tear, but let that old oak stand!

Note—In the 10th trial "I finished reading a letter which was remarked as gushing. When I sat down to recall some of the poem I remembered 'here too his sisters played in all their gushing joy.' When I tried to fit it into the verse I found that I had remembered it backwards."

In the 4th trial "I had been thinking for a long time but got nothing new. At last I read what I had written and I began wondering what it was that made him cry in line 4 verse III. Then I remembered that it was something about his mother and father. I repeated to myself 'My mother and father,' 'My mother and father' until I thought of the line."

When the subject got the 4th line of this verse she could not locate it in the poem.

No. 4. IV

11th and
12th Trial. My heart-strings round thee cling, close as the bark old friend!

13th Trial. Here shall the wild bird sing and still thy branches bend.
Old tree, the storm thou'lt brave, and woodman leave the spot;
While I've hand to save thy axe shall harm it not.

Note—In the 11th trial "I had just finished reading 'Apollo and Daphne'. Daphne turns into a tree and her garments become her bark. This made me get the last half of line 1."

In the 13th trial "While I was telling a story to a group of children one of them annoyed me so much that I finally said 'Jack, leave the room.' I said it so dramatically that we all laughed and when I was thinking of it later it reminded me of the way I had said 'Woodman, leave the spot.' Then the verse came to my mind."

In the 9th trial the subject got nothing new.

She did not indicate the date of each trial.

One can see that, although the lines came up in the most perverted order they, as well as the stanzas, finally found their proper places.

QUOTATIONS FROM "SNOW BOUND"

Recalled by G. M. after an interval of ten years.

"1. The sun that brief December day
2. Rose cheerless over hills of gray,
3. And, darkly circled, gave at noon
4. A sadder light than waning moon,
5. Slow tracing down the thickening sky
6. Its mute and ominous prophecy,
7. A portent seeming less than threat,
8. It sank from sight before it set.
9. A chill no coat, however stout,
10. Of homespun stuff could quite shut out,
11. A hard, dull bitterness of cold
12. That checked, mid-vein, the circling race
13. Of life blood in the sharpened face,
14. The coming of the snow-storm told.
15. The wind blew east; we heard the roar
16. Of Ocean on his wintry shore,
17. And felt the strong pulse throbbing there
18. Beat with low rhythm our inland air."—The original.

Notes—On January 12th the subject recalled the first eight lines correctly except that he substituted "A" for "Its" in line 6. At this first recall he also got lines 11, 15, 16, 17, 18, and two lines from Quotation II.

Lines 9 and 10 were recalled correctly on January 16th but it was not until February 1st that they were marked "Sure."

Line 11.
Jan. 12th. A dull chill bitterness of cold
Jan. 16th. A dark dull bitterness of cold
Feb. 1st. A hard dull bitterness of cold (correct)

Line 12.
Jan. 16th. Thought line ended in "race".
Later. That checked mid-life the —— face,
Later. That checked mid-vein the encircling race,

Line 13.
Jan. 16th. Of life blood in the hardened face,
Jan. 17th. Of life blood in the darkened face,

Line 14. Omitted.

Line 15.
Jan. 12th. Correct.
Feb. 1st. Placed it after line 13.

Lines 16 and 17.
Jan. 12th. Correct.

Line 18.
Jan. 12th. Beat with low rhythm the wintry air.
Jan. 15th. Beat with low rhythm our inland air.

QUOTATION II.

"1. Unwarned by any sunset light
2. The gray day darkened into night,
3. A night made hoary with the swarm,
4. And whirl-dance of the blinding storm;
5. As zigzag wavering to and fro
6. Crossed and recrossed the winged snow;
7. And ere the early bedtime came
8. The white drift piled the window-frame,
9. And through the glass the clothes-line posts
10. Looked in like tall and sheeted ghosts."—The original.

Line 1.
Jan. 23rd. And ere the early candle light
or
Long ere the time for candle light
Jan. 26th. Unwarned by sunset's mellow light
Jan. 27th. And ere the time for —— ——
Feb. 1st. And ere the time for candle light
Feb. 7th. Line above was marked correct.

Line 2.
Jan. 16th. The twilight softened into night,
Jan. 26th. The gray day softened into night, (Marked "sure")
Feb. 1st. Same as above. *Darkened* had been crossed out and *softened* written in.
Feb. 7th. The gray day darkened into night, (Correct)

Line 3.
Jan. 27th. A night made hoary with the blast
Feb. 1st. A night made (wretched with the flow)—doubtful
Later. A night made bitter by the blasts

Feb. 7th. A night made bitter by the frost
Later. A night made dreadful with the storms
Feb. 11th. A night made blinding by the swarm (Marked "sure")
Line 4.
Jan. 27th. Of snow flakes driving thick and fast;
Feb. 1st. Of snow flakes and the driving snow;
Later. Of snow flakes and the rising masts;
Feb. 7th. And ghost like with the rising forms;
Feb. 11th. Of snow flake and the blinding storm;

Note—Grouping lines 3 and 4 of the same date the vain attempt to reconstruct by rhyme is manifest.

Lines 5 and 6.
Jan. 14th. Correct.
Line 7.
Jan. 12th. And ere the early bed-time (or evening) came
Jan. 19th. And when the early evening came
Later. And ere the early bedtime came
Line 8.
Jan. 12th. The snow had piled the window frame
Jan. 13th. The snow drifts piled the window frame
Line 9.
Jan. 12th. Appeared the covered posts
Jan. 13th. And from below the covered posts
Jan. 14th. And from below the haunted (or mounted) posts
Jan. 19th. —— —— —— —— —— posts
Jan. 23rd. And from without the mounted posts
Jan. 27th. And from without the snowclad posts
Feb. 5th. And from without the vaunted posts
Feb. 12th. And from without the clothes-line posts
Line 10.
Jan. 12th. —— —— —— —— haunting ghosts
Jan. 13th. Looked in like tall and sheeted ghosts.

THE PAINTER OF SEVILLE BY SUSAN WILSON.

Recalled by C. M.

Subject C. M. over a period of nine months reconstructed 132 lines of a poem of 183 lines which she had not recalled for about 5 years. Although her records show a gain of 101 lines in the 10 subsequent recalls over the first recall, space does not permit a complete analysis of her data. In her final recall only 15 words and phrases were wrongly used. There is no absolute certainty, however, that the selection had not been learned with some of these wrong words. While the substitutes are rarely synonyms almost all of them have obvious likeness in meaning to the correct words and none make a break in the story's thread. Some of them were *gleamed* for *beamed, proving how fruitless is the teacher's power* for *to prove how vain must be the teacher's care, fair* for *rich, failed to tell* for *did not tell, whispered* for *murmured, gleamed* for *shone, enrapt* for *absorbed, humble* for *trembling.*

The variations in words and phrases in successive recalls are worthy of note.

1. Only a *boy* the *lad* had seen Feb. 8th became
   Almost a *child* the *lad* had seen Feb. 9th (a) became
   Almost a *child* the *boy* had seen Feb. 9th (b) (Correct) became
   Almost a *child* the *lad* had seen Final. Nov. 1st.
2. *Gleaming* Feb. 8th became *glowing* Final (Correct).

3. *Shed* or *spread* Feb. 9th became *shed* (correct) Final.
4. *Softly* Feb. 9th became *mildly* (correct) became *kindly*. Final.
5. *Watch* Feb. 9th became *guard* (correct) May 4th and Final.
6. *And answered* March 18th became *and whispered* July 27th became *and said "I swear it"* Nov. 1st and Final.
7. *Shone* July 28th (a) became *glowed* July 28th (b) became *gleamed* (incorrect) July 29th and Final. *Beamed* was correct.
8. *Morning sunlight* or *early sunlight* July 28th became *early sunlight* (correct) Final.
9. *Gleaned* or *fell* July 29th became *gleamed* (correct) Final.
10. *Choice pupils* July 29th (a) became *young aspirants* July 29th (b). *Young aspirants* (correct) Final.
11. *Showing* or *proving* or *to prove* (correct) July 29th became *proving* Final.
12. *Teacher's part* July 29th (a) became *teacher's task* July 29th (b) became *teacher's power* (incorrect) Final. *Teacher's care* was correct.
13. *Long got knowledge* July 29th (a) became *unbought knowledge* (correct) July 29th (b) and final.
14. *Painter* or *Murillo* Feb. 9th became *Murillo* (correct) Final.
15. *Toiled* Feb. 13th (a) became *worked* Feb. 13 (b) became *joyed* Feb. 13th (c) (correct) and final.
16. *So be thee from this day* Feb. 13th became *So be thee from this time* (incorrect) Final. *So be thee mine by other bonds* was correct.
17. *Stroke* Feb. 15th became *touch* (correct) Final.
18. *Pressed* Feb. 13th became *clasped* March 18th became *pressed* (correct) Final.

One may conclude from the above that the "corrections" are practically always made in the right direction and that the errors are in words and not in content. In her introspections the subject stated: "I always got the story before the words." "When the lines 'But constant to his purpose still. He toiled to see his pupil gain' were first recalled I gave *worked* and then *toiled* for *joyed* but realized that it was incorrect. I knew that there was the thought that Murillo found pleasure in helping Sebastian. This thought was not expressed in *toiled* or *worked* but came with *joyed.*"

There are two sections of the poem lines 1 to 18 and 64 to 72 which have similar beginnings:

"'Twas morning in Seville; and brightly beamed
The early sunlight in one chamber there;
Showing, where'er its glowing radiance gleamed,
Rich varied beauty."

and

"'Twas midnight in Seville; and faintly shone
From one small lamp a dim uncertain ray,
Within Murillo's study."

Until the 18th recall the subject gave lines 64 to 72 as the beginning of the poem. It was at this time that lines 1 to 4 were recalled.

In connection with lines:

"Nor dare to close your eyes in sleep
If on the morrow morn you fail
To answer what I ask
The last shall force you—do you hear?
Hence to your daily task."

The subject confused a phrase of another poem—"The Vision", "Thy faithfullness to show." "This phrase came up every time I got

here and disturbed my going farther altho I knew it did not belong here."

In the final recall when the parts from the previous recalls were put together 12.5 lines were added and distributed as follows: 1, 1, 1, 8, 1.5. The subject did not realize, however, that these were being added. This fact emphasizes the interdependence of associated units, and is a vivid example of now-conscious memory.

Usually the recalls were made in groups of several lines. One rhyming word brought up another line. One line or part of one line rarely came up alone. She recalled at very irregular intervals. When February 14th she succeeded in dragging herself to do her best she made several recalls during the evening. She became obsessed with the task and was disturbed on lying down to sleep, by incompleted parts fleeting through her mind. She awoke in the night recalling some new parts. The whole day following she was distressed by the feeling of failure to recall what she was sure she could recall. During the day and previous evening she added in all 25 lines. Probably several hundred attempts were made with one part or another. The experience was so unpleasant that the subject ignored it and refused to write any recalls and tried to forget all about it so that although 4 lines came up 2 days later no more recalls, nor attempts at recall, were made until July 29th. She again evaded the task until November 1st. She noted then that if she could only get a few connecting words she could finish it. After reading the original to compare it with her final recall she repeated the entire poem in perfect order with only 9 words wrongly used.

In the table appended the numbers in each column opposite the ordinates represent the number of lines in the successive recalls. The total of each column is followed in order by the number of lines in the original selection, the per cent of the entire selection which was given in the first recall, the per cent added by subsequent recalls, the total per cent recalled, the number of attempts at recall and the number of days in which recalls were made.

Although the first recall was the best for each selection a number of subsequent recalls are not very inferior. The efficiency decreases with succeeding recalls but the decrease is by no means constant. On the average almost 50 per cent of the original selection was added after the first recall. It should be noted that at the end of practically every recall the subject felt certain that no more could be added then, although the feeling that more could be added by keeping at it long enough was reported a number of times. Indeed with enough trials, perfect reconstruction might not have been impossible. There seems to be no correlation between the first recall and the total of subsequent recalls. The individual with the second lowest per cent for first recall made by far the greatest gain in the total subsequent recalls. The ratios of the first recall to the total of subsequent recalls are .45, .75, 1.66, .23, 1.71, .29. From the above facts one may conclude

AMOUNT, GAIN AND DISTRIBUTION OF RECALLS

	Wreck of the Hesperus —G. W.	Psalm of Life —G. M.	Psalm of Life —G. W.	Woodman, Spare that Tree—M. S.	Lady of the Lake —M. W.	Painter of Seville —C. M.
1	18	12	20	3	6	30.5
2	14	4	1	2	1	10.5
3	2	8	0	1	1.5	12.5
4	3	4	2	1	0	8
5	10	0	6	.5	.5	8
6	4		1	.5	.5	3
7	0		1	1		2
8	0		1	2		7
9	1.5		0	0		3
10	0			1		1
11	0			.5		4
12	3			.5		10
13	0			3		1.5
14	2					.5
15	0					5
16	0					2
17						2
18						4
19						5
20						12.5
Total number of lines given	57.5	28	32	16	9.5	132
Number of lines in poem	88	36	36	16	10	183
Per cent given in first recall	20.4	33.3	55.5	18.8	60	16.6
Per cent added in subsequent recalls	44.9	44.4	33.3	81.2	35	55.5
Total percentage given	65.3	77.7	88.8	100	95	72.1
Number of attempts at recall	16	5	9	13	6	20
Number of days covered in recalls	13	5	8	13	6	10

that the final recall is not a fair measure of retentiveness; much less is the first recall such a measure.

Because a number of the lines recalled from "Snowbound" by G. M. underwent so many changes and since he made no final reconstruction of all the recalls no attempt to enumerate his recall was made. Reference to his recalls readily show a comparatively high amount of the total recall given in the first recall. Those lines given in his first recall he had recalled very frequently during the five years interval but the suc-

ceeding lines had practically always failed to come up and had consequently been ignored. He reported the same for the first recall from the "Psalm of Life." G. W. whose first recall also was relatively high made a similar report. This corroborates experimental evidence of the value of recalling material once learned in assuring its retentiveness.

Recalling Names of Classmates

The writer G. C. M. tried to recall over a period of three months the names of his 76 classmates (1905). During that year he readily knew each one by name.

Feb. 24. He recalled the names of 31 and the faces of 3.

Feb. 26. He added 7 names and 3 faces.

Mar. 1. He added 6 correct and 2 incorrect names, the latter being marked *doubtful.*

Mar. 3. He began to recall by order of the alphabet and added 6 correct and 4 incorrect names (marked doubtful). Carter was given for Arter; Dixon for Hixon, and among the correct recalls was the name of one whose face only was recalled on Feb. 24th and 26th.

Mar. 6. He added 5 correct names, and 4 incorrect of which 3 were marked *doubtful.*

Mar. 8. He added 4 names. Arter was disguised in Alter but after a few minutes became Arter.

Mar. 10. He added one correct and one incorrect (*doubtful*) name. "Here I got the name of her whose face I had recalled several times before but for whom no other name but *Apples* and *Cider* would come up. She had often suggested these things to me while we were at school together. There was nothing in the sound of the name to suggest these words."

Mar. 12. He added two wrong words labelled *doubtful* and gave up in despair after 7 minutes although all previous recalls lasted for 15 minutes or more.

Apr. 22. He added 2 correct words, making a total of 62. Immediately after this recall he saw a picture which he had not seen during the experiment thus far, of all the class save one, and recognized only 56. "I later discovered that some I had recalled I could not recognize. I probably had recalled their names by mere sound associates. I did not look over the recalls in the meanwhile."

May 14. Sixty were recognized. G, S and B neither recalled nor recognized before, and one not recognized before were given. "The name of certain ones not recalled in looking over the picture, sometimes came up after I had passed

on to others; for example, for the face of X, I could not get a name but I felt troubled because I was certain I really knew her name. After writing the names of the next three, not trying to think of X, her name flashed to my mind. This happened quite frequently in recognition. Of course the imperfection of the photograph might be responsible for some poor recognitions.

C. E. M. ran the same test on herself with practically the same results.

Some other studies of delayed recall may be of interest here. Colvin[1] concluded that "recall after 24 hours seems to be as good, on the whole, as immediate recall, when tested by the method of parts retained." Similar findings were reported by Radossawljewitsch.[2] Huguenin[3] found that the number of lines of poetry which can be recalled ten minutes after learning is less than the number reproducible at any subsequent time (up to eight weeks). The writer elsewhere found that of 47 boys, "21 gave more words in the second recall (after one hour) than in the first (immediate) recall,—with an average of two-tenths of a word more in the second than in the first recall." Forty-five out of 73 girls gave more in the second recall, with an average of .97 words more. For both sexes, from one to six correct words were added in the second or third recall.[4]

Conclusions

On the average the gain in the total subsequent recalls was about half as much as the original selections and about twice as much as the first recall.

Certainty for validity of recall was surprisingly safe, while certainty of inability to recall more at any time was highly unsafe. The more frequent the recalls, however, the more reliable the certainty for each. Recalls marked *doubtful* were incorrect as a rule but a few marked *wrong* were correct.

Although some errors persisted throughout most were corrected in subsequent recalls. More attempts at correction were made when all the recalls were reconstructed into a unit (final recall) and these attempts were nearly always suc-

[1] Colvin, S. S. Development of Imagination in School Children. *Psychol. Rev. Mon. Sup.*, 1909, 11, 85-124.

[2] Radossawljewitsch. Das Behalten und Vergessen bei Kindern und Erwachsenen nach experimentellen Untersuchungen. Leipzig, 1907.

[3] Huguenin, C. Revivescence paradoxale. *Arch. de psychol.*, 1914, 14, 379-383.

[4] Myers, G. C. Recall in Relation to Retention. *J. Ed. Psychol.*, 1914. 5, 119-130.

cessful. In all recalls the changes made were generally in the right direction. When alternatives were given the correct one almost invariably survived. Unreasonableness of a recall, at times challenged its correction. Errors were in words and rarely in content; the content, as a rule, was recalled before the words. In a few cases remnants from foreign selections obtruded themselves causing considerable confusion.

Feeling and general attitude of the subject toward the task factored highly in the recall-performance. Frequently the subjects reported that they could get more if they would keep at it but they could not drive themselves to try. A few were "captured" by the task so that it could not be dismissed at will. For them many remnants were recalled at the most unexpected moments.

Casual suggestions by sounds, sights, movements, ideas and feelings served to call up remnants in various proportions. For some subjects this was very pronounced while for others it was rare.

Recall of rhyming words proved a great aid in bringing up the rest of the respective lines.

The parts of the selections were not always recalled in order, nor were they reported in order, except in final reconstruction. Even within a stanza or a paragraph, recalls sometimes were made in the most perverted order.

There was practically no correlation between the first recall and the total subsequent recalls.

Selections with many recalls previous to the experiment were reproduced much better than those with few or no recalls.

These findings go a long way to substantiate the belief that, "We never wholly forget anything." Certainly we do not forget nearly so much as we think we do, and one's inability to recall facts on demand, is no proof that one has really forgotten them.

The recall time which has been almost wholly neglected in memory experiments is probably as important in measuring memory as the learning time. At best, persistency of the subject is a big factor in recall.

Pedagogically one may infer that if the teacher were skillful enough in questioning and in general presentation the most of what seems to have been forgotten by the pupil could be recalled as needed. Likewise if all that is studied could be properly correlated, the amount to be memorized would be comparatively small.

Motive, and deep seated interest on the part of the learner

not only incite to greater activity, but, by evoking non-conscious recall they assure better results from the same expenditure of effort.

Some Suggestions

In the light of this study a few suggestions are offered:

1. Wherever possible recall time should be measured or standardized.

2. Some method should be devised for recording quantity and quality of recalls during the various stages of the recall time.

3. Further correlations of recall time with learning time and with recall performance should be studied for each recall.

4. Incorrect recalls should be taken into consideration and their transition through subsequent recalls for each individual should be noted.

5. Whenever possible, a number of subsequent recalls should be made. The more numerous they are and the greater the time over which they are spread the more instructive they probably would be. Subsequent recalls should not be expected by the subject.

6. Some scheme might be devised whereby certain suggestions could be measured as to their influence in evoking correct recalls.

7. Perhaps delayed recall offers the richest field for memory study.

The writers acknowledge their indebtedness to Misses Martha Sullivan, Dorothy Tooker, Margaret Wharburton, and Grace White, students of Psychology of the Brooklyn Training School for Teachers, for the indispensable part they performed in this study.

AN EXPERIMENTAL STUDY OF ECONOMICAL LEARNING

By H. E. CONARD, High School of Commerce, and G. F. ARPS, Ohio State University

I

Introductory. The complaint that high school students are unable to perform fundamental computations with speed and accuracy is emphatic and of long standing. The time devoted to arithmetical instruction in the elementary school is disproportionate to the results obtained; and this will remain true while methods of teaching remain unsupported by methods of learning. What is true of the elementary school is only less true of the high school. It is not an exaggerated statement to affirm that the work in arithmetic could be accomplished in two-thirds of the time now required, if more economical methods of learning were employed and an ideal of speed and accuracy developed.

Meuman[1] emphasizes the necessity of supplementing methods of teaching by methods of learning: "This question (of economical learning) becomes the more pressing in modern times because our courses of study, in their attempt to comply with the increasing requirements of practical life, are becoming more and more exacting in the demands which they make upon the memory tasks of school children." Curriculum building is all in the direction of addition of subject matter without hint of compensation by subtraction. If over-burdening of the child is to be avoided it would seem that either subtraction must keep pace with this addition or the rate of learning must be increased by economy of method.

II

The Problem. The primary purpose of this study is to determine quantitatively the superiority of a method which eliminates unessential processes in the four fundamental operations. Otherwise stated, the purpose is to determine the loss in speed and accuracy accompanying the traditional methods of teaching the four fundamental operations. The two methods will be referred to in this study as the 'traditional' and 'economical' methods.

[1] The Psychology of Learning, p. xiv.

The solution of the problem in the margin may serve as an illustration of the waste and fatigue in the prevailing method. When each digit and connecting terms are definitely expressed no less than seventy-one articulations are required. This number is increased by sixteen when the carrying process is formally expressed. Various abbreviations of this procedure are employed but it is exceptional to find a first year high school pupil who, by merely naming results, employs as few as seventeen in the solution.

245
987
621
876
912
543
4,184

The difference between the eighty-seven and seventeen expressions represents so much waste and fatigue. Other things being equal, the speed attained should increase with an approach to the smaller number of words. Special attention to the training of the pupils in group addition would enable them further to reduce this number to a minimum of ten words or less. In this study pupils were not trained in group additions for the reason that it would obscure the present problem and for the additional reason that the manner of grouping would not be uniform for all pupils. The traditional and the economical methods would both be proportionally shortened by application of group addition.

Experiments by Pintner,[2] Huey,[3] and Dearborn,[4] show conclusively that articulation in silent reading hinders both rapidity and efficiency of thought getting. As in reading, so in arithmetic, the direct linking of visual forms of digits and groups of digits, without the cumbersome and fatiguing audito-motorizing mechanism, leads to greater rapidity and accuracy in arithmetical computation.

III

Procedure. The Courtis Tests in Arithmetic were given to seventy-six first year high school pupils. From this number sixty-four were selected and divided into two equal groups, each group having approximately the same average initial speed and accuracy. Group T was drilled in the traditional method and Group E was trained in the economical method. Both groups were given identical problems in each of the four fundamental operations. All objective conditions were equalized as completely as possible.

Each group was urged to solve the entire list of twenty-eight problems as rapidly and accurately as possible. The

[2] 'Silent Speech,' *Pintner, Psychological Review*, 1913.
[3] 'The Psychology and Pedagogy of Reading,' *Huey*, 1900.
[4] 'The Psychology of Reading,' *Dearborn, Archives of Philosophy*. Vol. 4, 1906.

instruction given Group E differed from that given Group T only in the added direction that they must 'think results only.' The first column in the illustrative problem given above, therefore, would be read 5, 11, 12, 19, 24, and the second column 6, 7, 14, 16, 24, 28, 8. It should be stated that this group was frequently reminded to "think in terms of results only," since there was evidence that old habits functioned persistently.

There were eight work periods for each group. To equalize the amount of practice for the two groups, and for all the individuals, the work-limit[5] method was chosen in preference to the time-limit method. During a given work period each pupil solved seven problems in each of the four fundamental operations. The two groups practiced at different periods; Group T at the beginning, Group E at the close of the session, thus giving the former group what is commonly regarded as the more favorable hour.

IV

Experimental Material. It was especially desirable to make all the problems of the various sets of equal difficulty. To this end, the nine digits were made to recur with the same frequency. It is probable that such usage of the digits secures a desirable distribution of fatigue to the problems of a given set and also makes possible a uniform basis of comparison of work accomplished in the successive work periods.

Each problem in addition consisted of six three-digit numbers. The problems in subtraction involved two nine-digit numbers. In multiplication, the multiplier was a one-digit number in order to avoid the increase of addition processes by adding several partial products. In division, the divisor was a single digit so as to confine the processes as narrowly as possible to division only. The digits one and two were not used as multipliers or divisors.

V

Results. To provide a standard measurement of results, the Courtis Tests were given again after the last work period.

[5] To enable pupils to record the time required for the completion of the addition, subtraction, multiplication and division lists respectively, the time in seconds was recorded by the instructor every ten seconds in large figures on the blackboard. As soon as each set of problems was finished the last recorded time was written by the pupil in a place designated at the end of the set. This plan consumed none of the pupil's time in computing the number of seconds required for the several sets and removed a source of possible error. The time required for each of the four sets of problems was then obtained by the experimenter from the data sheets.

The relative efficiency of the two groups at the beginning of the experiment is shown in Tables I and II.

TABLE I

AVERAGES FOR COURTIS TESTS IN THE FOUR FUNDAMENTAL OPERATIONS

Group	Initial Test				Final Test				Improvements in per cent	
	Attempts		Rights		Attempts		Rights			
	Med.	Var.	Med.	Var.	Med.	Var.	Med.	Var.	Att.	Rts.
T	12.9	.24	12.0	.24	14.0	.20	11.7	.32	8.5	−2.5
E	12.5	.25	11.0	.28	16.8	.19	14.4	.24	34.4	30.9
Difference	.4	.01	1.0	.04	2.8	.01	2.7	.08	25.9	33.4
Superiority of E in (%)	−3.1	−4.2	− 8.3	−16.7	20.0	5.00	24.8	25.00	23.1	33.1

The former shows averages for initial and final Courtis tests with a comparison of efficiency and improvement of the two groups. The median number of problems attempted by Group T in the initial Courtis test was .4 higher than those by Group E. The median number of problems correctly solved by Group T was also higher by 1. The variability of Group T was less than that of Group E. This gives Group T an initial superiority over Group E. Table II gives a comparison of the average time required by the two groups to complete the seven problems in each of the four fundamental operations during the eight work periods. This table does not indicate an initial advantage for Group T, the average total time of Group E being five seconds less than that of Group T.

TABLE II

COMPARISON OF GROUP AVERAGES IN SECONDS
(With penalty added for errors)

Work Periods	Group T					Group E				
	+	−	×	÷	Total	+	−	×	÷	Total
1	172	199	211	218	800	169	213	200	213	795
2	141	192	193	172	698	169	193	195	177	734
3	162	148	224	219	753	183	168	228	246	825
4	138	134	186	191	649	161	152	205	190	708
5	161	196	188	177	722	164	175	172	172	683
6	154	182	199	192	727	144	141	177	173	635
7	140	187	185	181	693	129	173	173	179	654
8	144	186	183	172	685	125	163	163	148	599

The ordinates of the curves in Fig. 1 represent group averages in seconds for the eight work periods in the four fundamental operations. Each point of the curve, therefore, indicates the average number of seconds required by the group to solve the seven problems.

It was impossible, of course, to equate perfectly the intelligence of the two groups. In order to test more effectively the economic method, the values for the first work period of the various curves shown in Figs. 1, 2 and 3 were derived by giving both groups practice in the method which applied to Group T only in subsequent work periods. Obviously, this gives Group T a handicap of one work period in addition to the practice afforded by the initial Courtis test. A glance at the curves b and c, Fig. 4, indicates that the above mentioned handicap was unnecessary, since the curve for Group T already shows a superiority over Group E, excepting at point Att. in multiplication and at points, Att. and Rt. in division.

The handicap operates to the disadvantage of Group E in two ways,—it facilitates the efficiency of Group T on the one hand and accentuates the disadvantageous habits in Group E on the other.

The data in Tables III and III (a) for the initial Courtis Tests show that the median number of problems attempted by Group T was 1.2 higher than Group E in addition, .7 higher in subtraction, .3 lower in multiplication and .2 lower in division, giving Group T a total initial advantage of 1.4 "attempts." The median number of problems correctly solved by Group T in the initial Courtis Test was 1.6 higher than in Group E in addition, .7 in subtraction and 2.3 in multiplication and lower by .6 in division, giving Group T a total initial advantage of 4 "rights." These tables also show the initial variability in the number of problems attempted by Group E to be greater by 5% in addition, 5% in subtraction, equal variability in multiplication and 5% less in division,—an average initial disadvantage of 1.25% for the four fundamental operations. The variability of problems correctly solved by Group E was initially greater by 8% in addition, 9% in subtraction, 10% in multiplication and less by 9% in division,—giving Group T an average initial advantage of 4.5%.

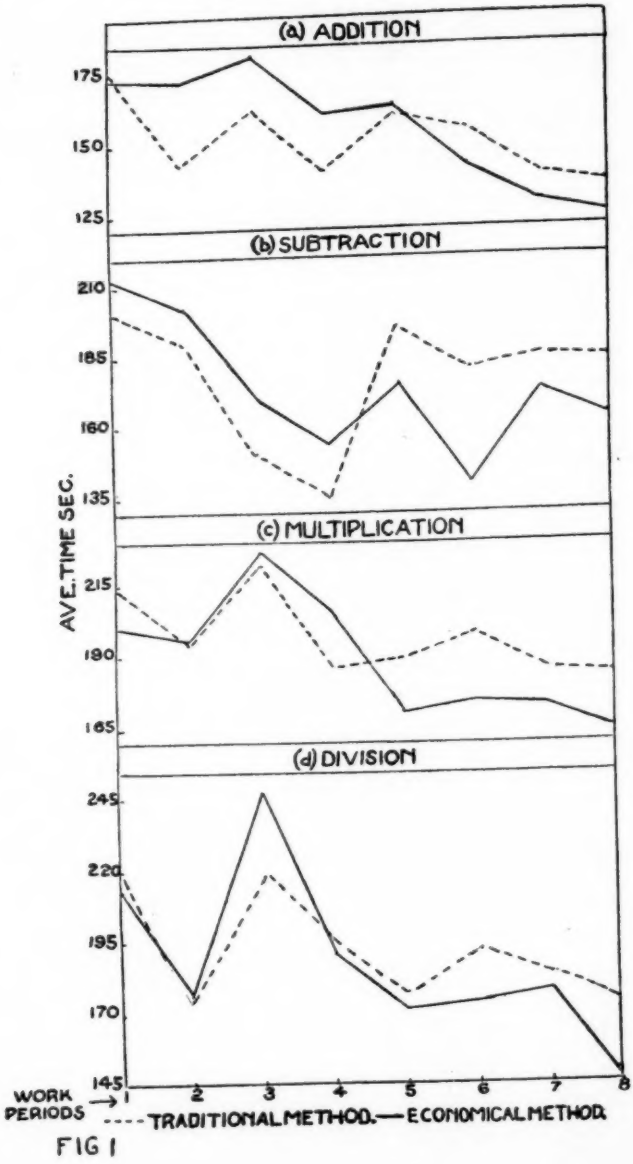

(a) ADDITION
175
150
125
(b) SUBTRACTION
210
185
160
135
(c) MULTIPLICATION
215
190
165
(d) DIVISION
245
220
195
170
145
AVE. TIME SEC.
WORK PERIODS →
1
2
3
4
5
6
7
8
---- TRADITIONAL METHOD. — ECONOMICAL METHOD.

FIG 1

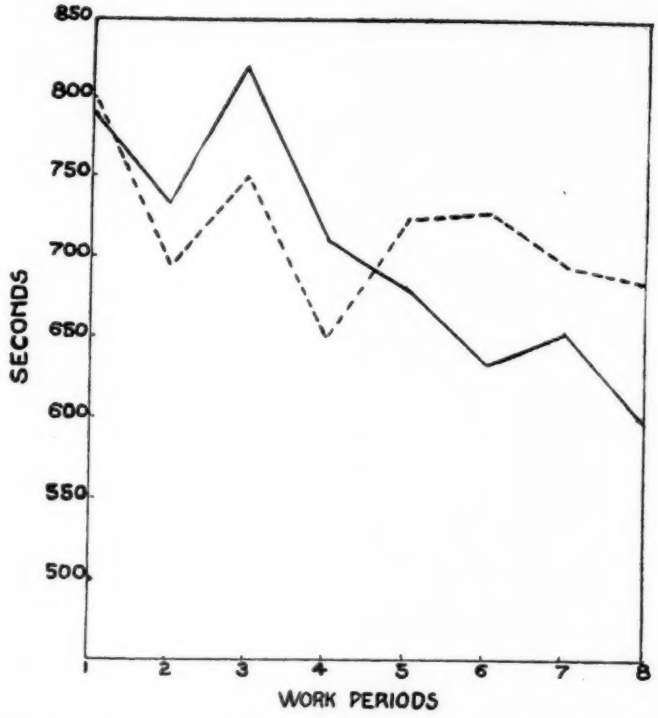


FIG. 2 LEARNING CURVE, showing total time each work period
GROUP E=——— GROUP T=- - - - - -

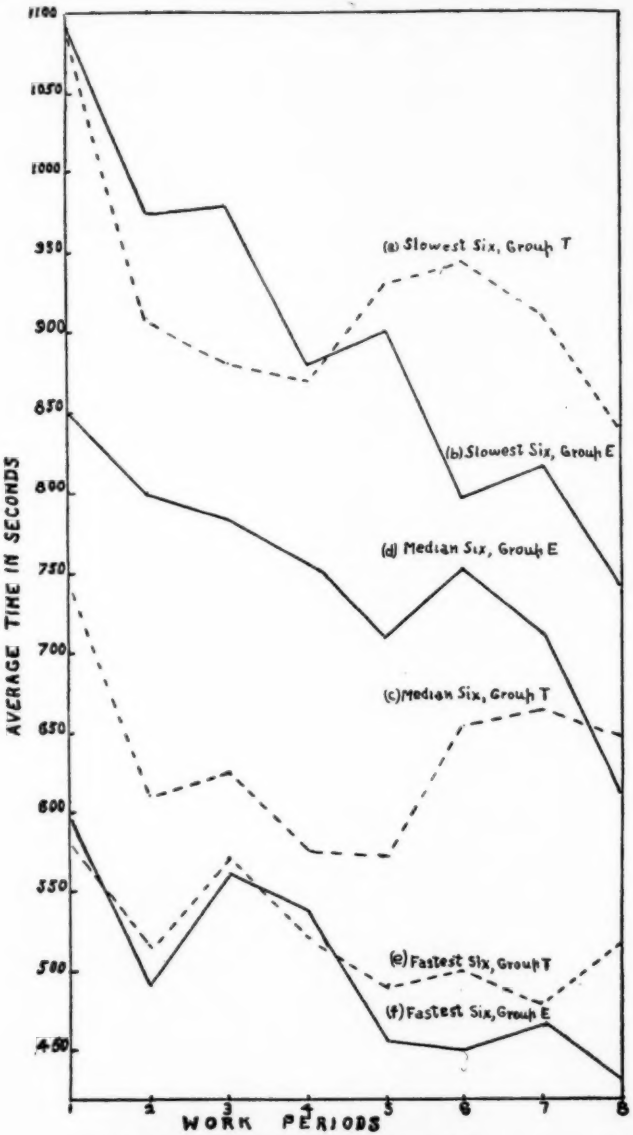


FIG. 3. LEARNING CURVES
FOUR FUNDAMENTAL OPERATIONS COMBINED

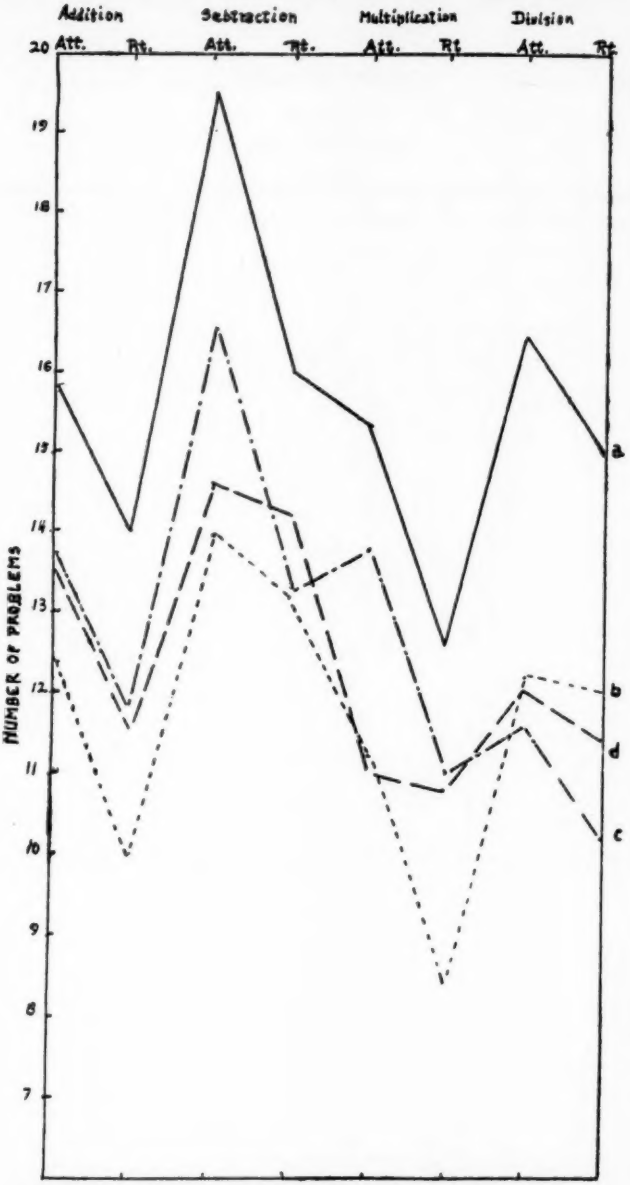


FIG. 4 INITIAL AND FINAL COURTIS TESTS

Att., Number of Problems Attempted. Rt. Number of Problems Right.

——— a, Final Test, Group E ----- b, Initial Test, Group E.

—·— ·C, Final Test, Group T. — — d, Initial Test, Group T

TABLE III

INITIAL COURTIS TEST

Group T

ADDITION					SUBTRACTION				MULTIPLICATION				DIVISION			
Atts.			Rts.		Atts.			Rts.	Atts.			Rts.	Atts.			Rts.
Frequency	Deviation	Score	Frequency	Deviation	Frequency	Deviation	Score	Frequency	Deviation	Frequency	Deviation	Score	Frequency	Deviation	Score	Frequency	Deviation
		24					24					24			24		
2		23			1		23					23			23		
		22					22					22	1		22	1	
		21			1		21	1				21			21		
2		20	3		1		20	1				20			20		
1		19					19	1				19	1		19	1	
		18			2		18		1			18	2		18	2	
1		17			4		17	1	1			17	1		17	1	
3		16	2		4	7	16	7	10			16	1		16	1	
1	5	15	2			4	15	4	9	3		15	2	3	15		
3	6	14	2	5	6	6	14	2	2	3		14	1	3	14	2	4
6	6	13	3	4	4		13	5		5	7	13	1	8	13	1	2
3		12	1	6	3		12	3		3	5	12	4	4	12	4	7
4		11	6	6	1		11	2		7	7	11	7		11	4	4
2		10	5		2		10	2		2		10	5	10	10	3	
2		9	1				9	1		2		9	3	5	9	1	
1		8	3		3		8	1		2		8	2		8	2	
1		7	1				7	1		2		7	7		7	3	
		6	1				6					6			6	2	
		5					5					5	1		5	4	
		4					4					4			4		
		3	1				3					3			3		
		2	1				2					2			2		
		1					1					1			1		
		0					0					0			0		
Ap. M..	13		11		14		14		11		10		12		11		
Cor.....	.7		.6		.7		0		0		.8		0		.5		
Med....	13.7		11.6		14.7		14		11		10.8		12		11.5		
M. D...	3		2.2		3		2.6		2.7		2.3		3.6		4		
Var.....	.22		.19		.20		.19		.24		.21		.30		.35		

Ap. M. = apparent median; Cor. = correction; Med. = median; M. D. = median deviation; Var. = Variability

TABLE III (a)

INITIAL COURTIS TEST

Group E

ADDITION					SUBTRACTION				MULTIPLICATION				DIVISION			
Atts.			Rts.		Atts.			Rts.	Atts.			Rts.	Atts.			Rts.
Frequency	Deviation	Score	Frequency	Deviation	Frequency	Deviation	Score	Frequency	Deviation	Frequency	Deviation	Score	Frequency	Deviation	Score	Frequency	Deviation
		24					24					24			24		
		23					23					23			23		
		22					22					22			22		
1		21					21					21			21		
2		20			4		20	2				20			20		
		19			2		19					19			19		
1		18	2		3		18	1				18	1		18		
		17	1			2	17	4		2		17			17		
1		16			4	9	16	1	3	2		16	1		16	1	
4	8	15			2	6	15	1	4	1		15	5	7	15	4	6
3	5	14			1	1	14	3	8	1		14	2	5	14	3	5
	2	13	2		4		13	3	3	4	10	13	3	6	13	2	5
7	7	12	4	9	5		12	5		3	7	12	5	5	12	6	6
2		11	3	7	2		11	3		3	3	11	3		11	3	
2		10	3	3	4		10	2		4		10	3		10	2	
4		9	4		1		9	4		6		9	2		9	2	
2		8	5				8			2		8	4		8	4	
2		7	1				7			4		7			7	2	
1		6	3				6	2				6	2		6		
		5					5					5			5		
		4	1				4					4	1		4	1	
		3	3				3					3			3	2	
		2					2					2	1		2		
		1					1					1			1		
		0					0					0			0		
Ap. M..	12		10		14			13		11			8		12		12	
Cor.....	.5		0		0			.3		.3			.5		.2		.1	
Med....	12.5		10		14			13.3		11.3			8.5		12.2		12.1	
M. D....	3.4		2.7		3.5			3.7		2.7			2.6		3.1		3.2	
Var.....	.27		.27		.25			.28		.24			.31		.25		.26	

TABLE IV

FINAL COURTIS TEST

Group T

ADDITION					SUBTRACTION					MULTIPLICATION					DIVISION				
Atts.			Rts.		Atts.			Rts.		Atts.			Rts.		Atts.			Rts.	
Frequency	Deviation	Score	Frequency	Deviation	Frequency	Deviation	Score	Frequency	Deviation	Frequency	Deviation	Score	Frequency	Deviation	Frequency	Deviation	Score	Frequency	Deviation
1		24			1		24					24					24		
1		23	2		1		23					23					23		
1		22			1		22	2				22					22		
		21			2		21	1		1		21					21		
		20					20					20			1		20		
		19	1		1		19	2				19					19	1	
		18			2	7	18	1				18			1		18		
2		17			5	6	17	3	10	5	6	17	1		1		17	1	
3		16	1	4	5	5	16	3	5	2	4	16	1				16	1	
2	5	15	1	1	1		15	1	2	1	6	15	4		1		15	2	
4	6	14	4	6	5		14	1	3	5	6	14	4		3	7	14	2	
6	6	13	1	3	1		13	3		5	5	13	3	6	3	8	13	2	6
2		12	5	5	3		12	1		1		12	2	7	4	3	12	1	6
3		11	2				11	2		3		11	4	4	3		11	4	4
2		10	2		2		10	7		4		10	5		4		10	4	
4		9			1		9	1		1		9	3		4		9	3	
1		8	3		1		8	2		1		8	1	2	3		8	4	
		7	6				7			1		7	2		3		7	2	
		6	1				6	1		2		6			1		6	1	
		5	3				5					5	2	3			5	2	
		4					4	1				4					4	2	
		3					3	1				3	1				3	1	
		2					2					2					2		
		1					1					1					1		
		0					0					0					0		
Ap. M.	13		12		16			13		13			11		11			10	
Cor.	.8		0		.6			.3		.8			0		.6			.3	
Med.	13.8		12		16.6			13.3		13.8			11		11.6			10.3	
M. D.	2		4.5		2.9			3.7		3.3			3		2.6			3.5	
Var.	.15		.37		.18			.28		.24			.27		.22			.34	

TABLE IV (a)

FINAL COURTIS TEST

Group E

ADDITION					SUBTRACTION					MULTIPLICATION					DIVISION				
Atts.			Rts.		Atts.			Rts.		Atts.			Rts.		Atts.			Rts.	
Frequency	Deviation	Score	Frequency	Deviation	Frequency	Deviation	Score	Frequency	Deviation	Frequency	Deviation	Score	Frequency	Deviation	Frequency	Deviation	Score	Frequency	Deviation
		24			4		24	1				24			1		24		
1		23			3	6	23	1				23					23	1	
1		22			3	6	22	3		1		22					22		
		21	1			3	21	2		1		21	1		1		21		
		20	1			1	20	2	3	1		20	1		1		20		
3		19			5	5	19	1	3	3		19			2		19	2	
4	7	18			1		18	1	4	1		18	1		4	6	18	5	6
2	6	17	3	9	3		17	2	6	1	5	17	1		1	3	17	1	3
3	6	16	3	6	3		16	2	2	4	9	16	1		8	8	16	3	7
4	4	15	2	6	3		15	4		5	5	15	2	6	2		15	3	3
3		14	3	3	3		14	3		5		14	2	4	2		14	4	
4		13	4		1		13	2		4		13	7	9	2		13	2	
3		12	3		1		12	1		3		12	3	3	2		12	1	
4		11	6				11	2		3		11	2		1		11	4	
		10	5				10	2				10	2		2		10	1	
		9	1				9	2				9	6		1		9	2	
		8					8	1				8	3		1		8	1	
		7					7					7	2		1		7	2	
		6					6					6					6		
		5					5					5					5		
		4					4					4					4		
		3					3					3					3		
		2					2					2					2		
		1					1					1					1		
		0					0					0					0		
Ap. M..	15		14		19			16		15			12		16			15	
Cor.....	.8		0		.4			0		.4			.6		.4			0	
Med....	15.8		14		19.4			16		15.4			12.6		16.4			15	
M. D...	3.1		3.2		4.3			4.6		2.6			3.1		3			3.7	
Var.....	.20		.23		.22			.27		.17			.24		.18			.25	

In the final Courtis Tests we find, Tables IV and IV (a) that the median number of problems attempted by Group E exceeds that of Group T by 2 in addition, 2.8 in subtraction, 1.6 in multiplication and 4.8 in division,—a superiority of 11.2 problems. The median number of problems correctly solved by Group E exceeds that of Group T by 2 problems in addition, 2.7 in subtraction, 1.6 in multiplication and 4.7 in division,—a total superiority of 11 problems. In the final test the variability in the number of "attempts" was greater for Group E by 5% in addition, 4% in subtraction and less by 7% in multiplication and by 4% in division,—an average superiority of 5% for Group E. The variability of the number of "rights" for Group E in the final Courtis Test was less by 14% in addition, 1% in subtraction, 3% in multiplication, and 9% in division,—an average of 6.7% less variability for Group E.

With respect to the number of problems attempted at the close of the eight practice periods, Groups T and E improved 8.5% and 34.4% respectively; with regard to the number of problems correctly solved, Group T lost 2.5% while Group E gained 30.9%. (For summary see Table I.)

Fig. 9 graphically sets forth the relation of the medians and variability as given in Table I. The medians of the initial attempts for all four fundamental operations show very slight differences between Groups T and E. The arrows practically fall within a vertical line. This is not true for the medians of the final attempts and rights. Here the medians for Group E in both attempts and rights exceed that of Group T by 2.8 abscissae points. The median of final "rights" for Group T occupies a position .3 abscissae points farther to the left than its position in the initial test, showing a decrease in accuracy with the increase in speed.

The marked superiority of the economical method is clearly seen in curve a, Fig. 4. The greatest superiority is in division and the least in addition.

Figs. 5-9 show in a striking manner the decrease in variability under the economical method, the graphs becoming more compact around the median. This characteristic is most marked in the addition graphs (Fig. 5), showing decreased variability both in the number of final attempts and in the number of rights for Group E as previously stated. Group E excels Group T at and after the sixth work period (Table II) in addition, at the fifth period and thereafter in subtraction and multiplication, and at the fourth period and thereafter in division. The irregular rates of improvement for

both groups, apparent in the columns of totals (Table II) and in the graphs (Fig. 1), derived from Table II, indicate uncontrollable changes in attitude of pupils probably due to flagging interest and to unfavorable bodily and environmental conditions.

Individual records as well as fluctuations of group averages in the case of Group E indicate that the arithmetical habits acquired in the elementary school, asserted themselves more insistently in the 3rd and 7th work periods. Here we find a marked increase in the average time required for completion of the problems when a decrease should have been expected. Statements of some of the members of the group corroborate the conclusion.

The greatest amount of improvement is found in division of Group E (Table II). Here the average time required to solve the seven problems of the eighth work period was 65 seconds less than the time required in the first work period (213-148). The corresponding improvement for multiplication, subtraction and addition in Group E was 37, 50 and 44 seconds respectively. Improvements for Group T in the same order as given above for Group E were 46, 28, 13 and 28 seconds. The time required to complete the third work period of Group E was 246 seconds. This time exceeds that of any other work period of either group for any of the four fundamental operations. Here the average time was 27 seconds more than in the corresponding period and operation for Group T. This time, (246 seconds), for Group E was 33 seconds more than in the first work period, 69 seconds more than in the second work period and 98 seconds more than in the last work period. These figures are significant in view of the fact that it was at this point that the pupils complained most of the interference of their former habits. Moreover it was in the third period that the economical method was first really used by Group E. The pupils confessed to having used the traditional method during the second period because they found their desire for speed led them, unconsciously, to break away from the economical method and to lapse into the traditional method.

The greater difficulty in learning division and the greater final improvement agrees with results of Chapman.[6] He found that improvement with practice is always greatest in the more complicated processes. Division involves a greater variety of processes than any of the other three fundamental operations.

[6] Chapman, James Crosby, Thesis (Ph.D.), Columbia, 1914.

The irregular character of the learning curves for Group T is probably due to the waxing and waning of interest incident to the continuance of a method devoid of novelty. An effort was made to iron out the irregularity by giving each pupil a copy of his group record for the previous work periods, by calling attention to the achievements of superior pupils and by urging a maximum of effort on the part of all. The same incentives were given to both groups.

The curves in Fig. 2 are composites of curves a, b, c, and d of Fig. 1. Each point in the curves shows the total time required in each work period to complete the problems in addition, subtraction, multiplication and division. The efficiency of Group E, as shown by these curves, unmistakably exceeds that of Group T after the fourth work period. Accuracy is incorporated in the graphs of Figs. 1, 2 and 3 by adding to the group averages the number of seconds which would have been required, at the average speed, to correct all errors. Group T had 9/10 per cent of error and Group E 7/10 per cent for the average of the eight work periods. The total number of errors made by each group during each of the work periods and the average number of errors per pupil are given in Table V and the former is graphically shown in Fig. 10.

TABLE V

TOTAL ERRORS AND AVERAGE ERRORS PER PUPIL

Groups	Work Periods															
	1		2		3		4		5		6		7		8	
	T.	Av.	T.	Av.	T.	Av.	T.	Av.	T.	Av.	T.	Av.	T.	Av.	T.	Av.
T.	180	5.6	157	4.9	180	5.6	140	4.4	147	4.6	183	5.7	187	5.9	191	6.0
E.	173	5.4	135	4.2	100	3.1	112	3.5	134	4.2	119	3.4	152	4.7	140	4.4

The curves in Fig. 3 show the efficiency of the six initially fastest, six median and six slowest pupils of both groups. The increase of speed with practice is most conspicuous in curve b, the learning curve for the slowest six pupils of Group E. The difference between the average time in the initial and final work periods is 335 seconds (1086-751 sec.). The median six of this group decreased the average time 235 seconds (846-611), while the fastest six decreased it 165 seconds (595-430). The corresponding decreases in Group

T were 246, 103 and 55 seconds. These differences represent the time saved in the eighth work period as compared with the first.

The percentage of increase in speed was nearly uniform throughout Group E, while only the slowest pupils in Group T made noteworthy improvement with practice; but this improvement was much less than that made by the corresponding six pupils of Group E. The six slowest, the six median and the six fastest pupils of Group E surpassed the corresponding pupils of Group T at the fifth, eighth and fifth work periods respectively. Expressed in per cent, the slowest, median and fastest pupils of Group T improved 23, 13 and 9 per cent respectively while those in Group E improved 31, 28 and 28 per cent.

TABLE VI

Groups of Six Pupils	Improvement in Seconds		Improvement in Per Cent	
	Group T	Group E	Group T	Group E
Slowest	246	335	23	31
Median	103	235	13	28
Fastest	55	165	9	28

Summary and Conclusions

(1) According to the final Courtis Tests the group of pupils working economically shows the following striking superiority over the group working traditionally: (a) in the number of problems *attempted,* 11.2; (b) in the number of problems correctly solved, 1; (c) 6.7% less in variability; (d) with respect to the number of problems attempted at the close of the eighth work period 33.4%. (Group T actually lost 2.5%.)

These statistics gain enormously in importance when it is remembered that (1) the pupils working traditionally showed a decided superiority in the initial Courtis Tests, and (2) that Group E employed the method of Group T for the first of the eight work periods.

(2) Of the four fundamental operations, division shows the greatest absolute improvement in Group T as well as Group E. These values for Groups E and T are 65 and 46 seconds respectively. These results confirm the observations made by Chapman referred to above.

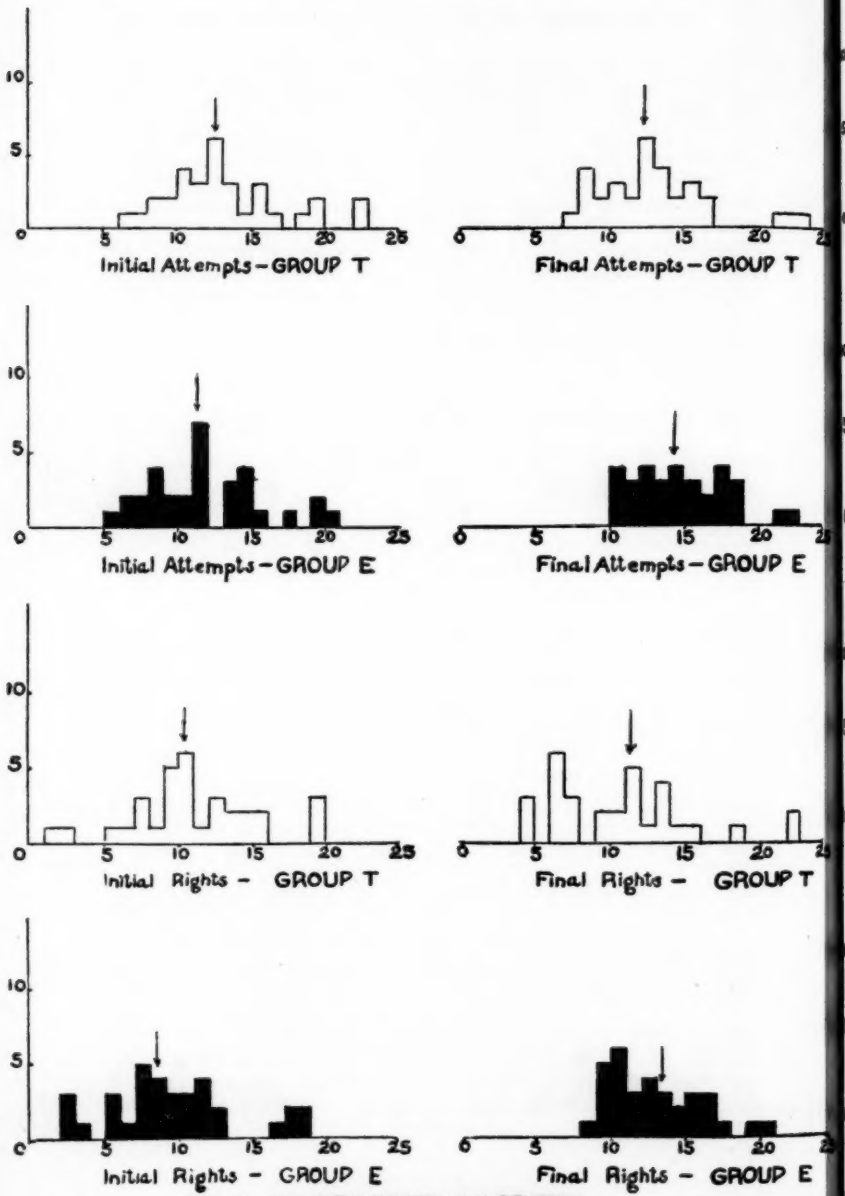
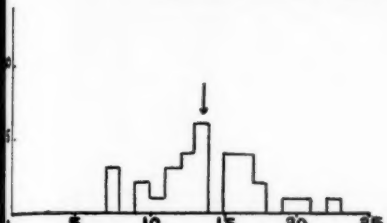
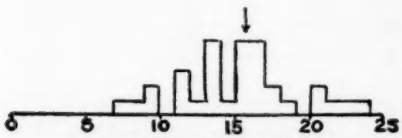

10
5
0
5 10 15 20 25
Initial Attempts – GROUP T
Final Attempts – GROUP T
Initial Attempts – GROUP E
Final Attempts – GROUP E
Initial Rights – GROUP T
Final Rights – GROUP T
Initial Rights – GROUP E
Final Rights – GROUP E

FIG 5, COURTIS TESTS IN ADDITION

ABSCISSAS = PROBLEMS ORDINATES = PUPILS



Initial Attempts - GROUP T

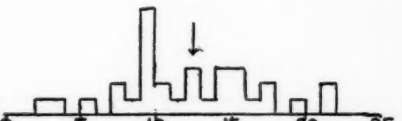


Final Attempts - GROUP T

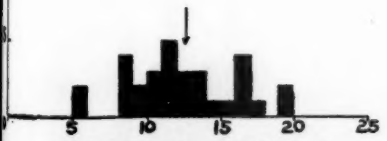
Initial Attempts - GROUP E

Final Attempts - GROUP T

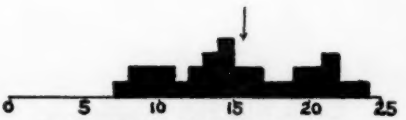
Initial Rights - GROUP T



Final Rights - GROUP T



Initial Rights - GROUP E



Final Rights - GROUP E

FIG. 6, COURTIS TESTS IN SUBTRACTION

ABSCISSAS = PROBLEMS ORDINATES = PUPILS

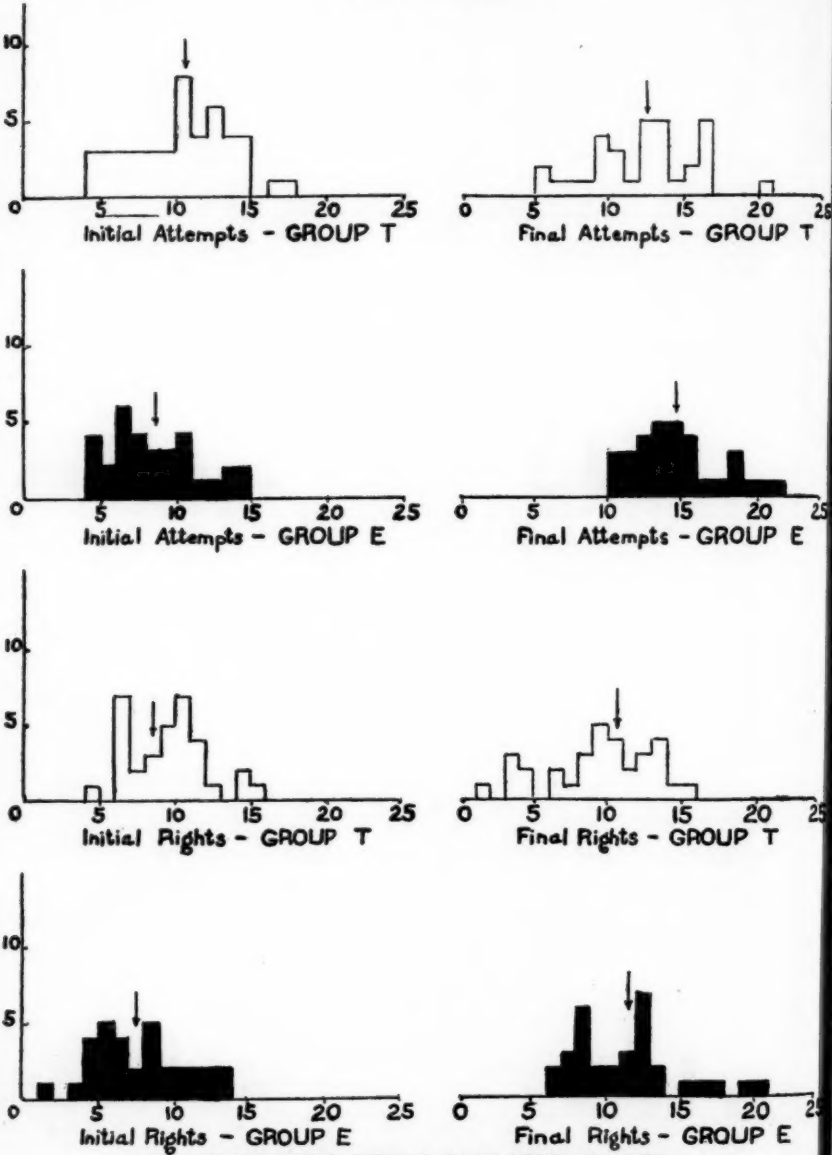

Initial Attempts - GROUP T
Final Attempts - GROUP T
Initial Attempts - GROUP E
Final Attempts - GROUP E
Initial Rights - GROUP T
Final Rights - GROUP T
Initial Rights - GROUP E
Final Rights - GROUP E

FIG. 7, COURTIS TESTS IN MULTIPLICATION
ABSCISSAS = PROBLEMS ORDINATES = PUPILS

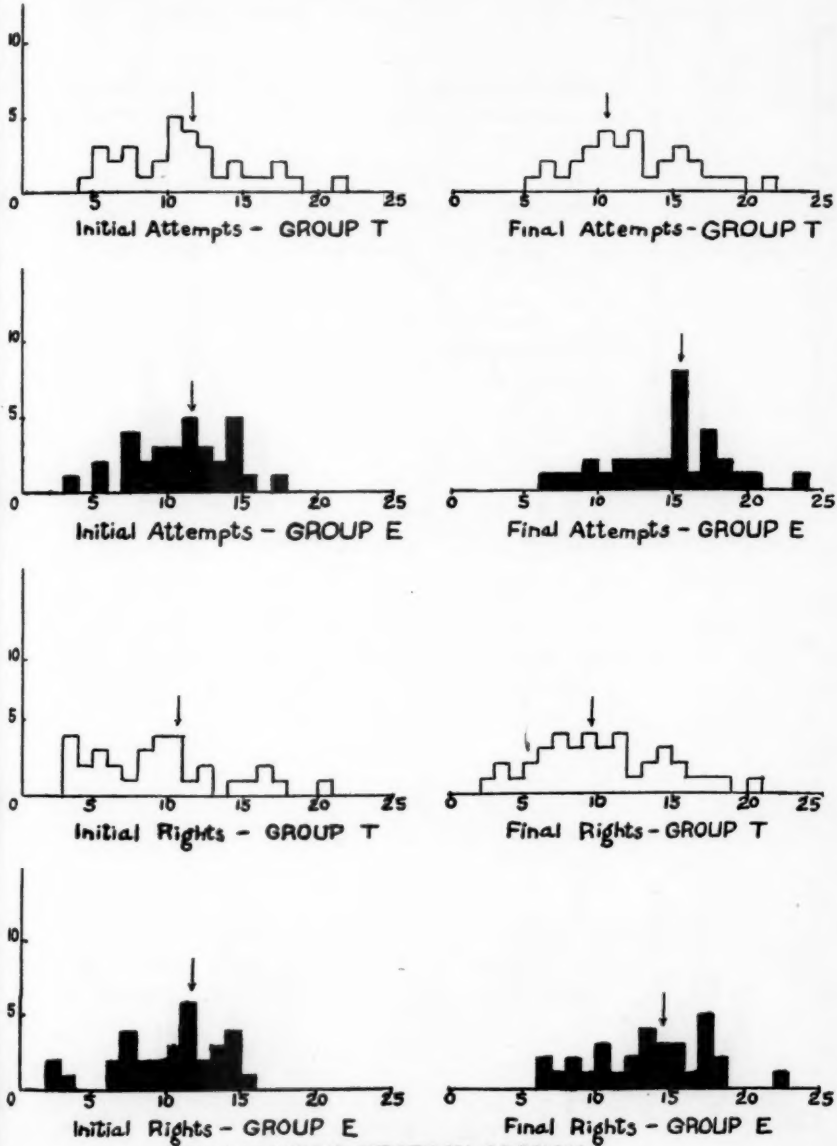

Initial Attempts - GROUP T
Final Attempts - GROUP T
Initial Attempts - GROUP E
Final Attempts - GROUP E
Initial Rights - GROUP T
Final Rights - GROUP T
Initial Rights - GROUP E
Final Rights - GROUP E

FIG. 8, COURTIS TESTS IN DIVISION
ABSCISSAS = PROBLEMS ORDINATES = PUPILS

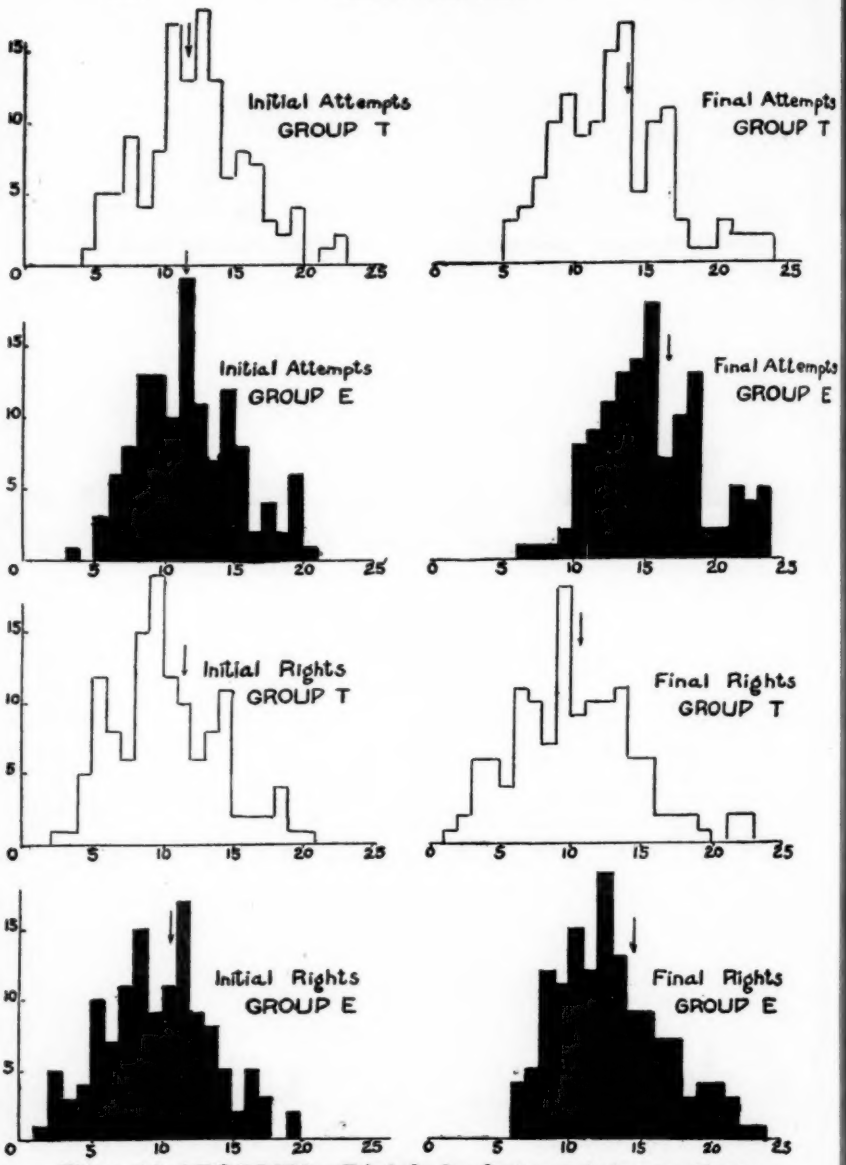


FIG. 9, COURTIS TESTS — Totals for four fundamental operations

(3) Individual records and group averages of Group E indicate that the interference of established habits of work manifest themselves irregularly. The phenomenon of interference was greatest in the third and seventh work periods.

(4) The superiority of the economical group is again shown in the reduction of the amount of time required to solve the problems of the last work period as compared with the first period. In this respect the economical group shows a higher efficiency than Group T by 19, 9, 37 and 16 seconds for division, multiplication, subtraction and addition respectively.

(5) The gain in speed of Group E over the corresponding pupils of Group T in the four fundamental operations combined, of the six slowest, six medians and six fastest pupils, is 90, 132 and 110 seconds respectively.

The adoption by elementary and secondary schools of the method of arithmetical computations employed by Group E would eliminate an important factor of waste and make possible a considerable reduction in the time now devoted to arithmetic. In the four fundamental operations it appears that pupils should be permitted to think in terms of results only and restrict, so far as possible, the audito-motorizing mechanism.

The economical method should be employed as soon as possible to prevent the formation of 'interference' habits and for the reason that the economical method is more favorable to the development of habits of attention.

NEW LABORATORY EQUIPMENT

By Christian A. Ruckmich,
University of Illinois

For many years the American Psychological Association has arranged for the display of apparatus at its annual meetings. Scattered articles on apparatus have appeared also from time to time in our psychological journals. Both of these methods of exposition reveal in its material aspects the growth of empirical psychology, but the author is strongly of the belief that there is not yet enough mutual coöperation in the way of improving our empirical resources in general and our laboratory equipment in particular. Committees have been at work on our laboratory methods, our laboratory experiments, and our class-room management; but, apart from special pieces of apparatus planned for particular researches, we have not yet an adequate exchange for ideas concerning laboratory equipment. The annual exhibition has not induced enough laboratories to participate and not all new pieces from our laboratories can be safely and conveniently transported. However useful these annual displays are—and the author does not mean to disparage them in any way,—accurate descriptions of apparatus in our journals, accompanied by illustrations whenever possible, are sure to appeal to a larger group and will leave a more permanent record in our archives. Demonstrations, in our opinion, are invaluable, but they ought to be accompanied by accurate specifications. By writing out in detail a series of descriptions of new equipment designed and constructed in our laboratory during the last few years, the author attempts to express his agreement with Seashore when he writes:

> The Cornell Laboratory has set a good example in reporting detailed specifications for the following five pieces of apparatus. It is very desirable that the various laboratories should adopt the plan of describing fairly permanent pieces of apparatus apart from the report of the research.[1]

TUNING-FORK OF VARIABLE INTENSITY.

The principle upon which the construction of this apparatus rests is that of wave-interference and virtual cancellation at points lying in planes which make angles of 45 degrees with

[1] Seashore, C. E. Apparatus, *Psychol. Bull.*, 10, 1913, 32.

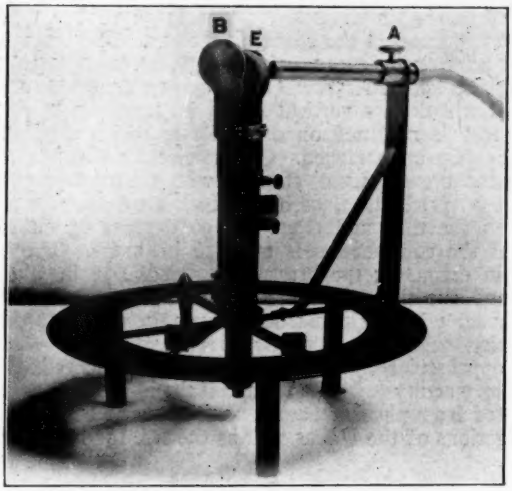


FIG. 1.—Tuning-Fork of Variable Intensity.

a plane passing midway between the tines of a tuning-fork and parallel to their sides. If the tines of a tuning-fork are therefore rotated opposite a conducting tube which is held stationary in a position perpendicular to the axis of rotation, a point of virtual cancellation of wave disturbance, together with phases of partial cancellation on either side, will pass the tube four times in a complete revolution.[2]

The fork is electromagnetically driven by means of a primary fork operated in series with it through the binding posts (D) and electromagnet (E), and removed to another room to eliminate extraneous noises. It is accurately tuned to a pitch of 100 vd. and the amplitude of its vibrations can be gauged to 1/1000 in. by means of a micrometer-screw (B) whose head, 1¼ in. in diameter, carries a scale indicating twenty-fifths of a revolution and whose stem, with 40 threads to the inch, permits the adjustment of its tip until contact is made between it and the side of the tine. A brass tube, 5 in.

[2] A similar form of apparatus has been suggested by F. M. Urban: Ein Apparat zur Erzeugung schwacher Schallreize, *Arch. f. d. gesam. Psychol.*, 27, 1913, 232-234. The principle of interference is described in detail in Barton, E. H. A text-book on sound, 1908, 374-377; Helmholtz, H. L. F. On the sensations of tone (trans. Ellis), 3rd Eng. ed., 1895, 161; Windelband, A. Handbuch der Physik, Vol. 2 (Akustik), 1909, 602.

long and ½ in. in diameter, and a large rubber tube connected to it, conduct the sound to the ear. The brass tube is held in position by means of an angle-brace, is adjusted by rotating the knurled screw (A), and terminates on the side nearest the fork in a vertical slit ⅜ in. long and ⅛ in. wide.

The fork is mounted on a spindle to which a handle and indicator (C) are attached. On the circular base the degrees of rotation are engraved, starting with the zero-point at the position in which the tines of the fork are both in a straight line with the tube and extending 90 degrees on either side. Most of the construction is of 1/16 in. brass. The base is 10 in. in diameter; the brass tube stands 6¾ in. above the base; and the three legs are 2¾ in. long and are covered with rubber tubing which extends over their ends to diminish conduction of sound through the base.

The apparatus readily lends itself to experiments in the field of auditory acuity (*cf.* note 1), and if the intensity is accurately calculated from physical equations, it ought to be of service in investigations of the *DL* as well as the *RL* for intensity.

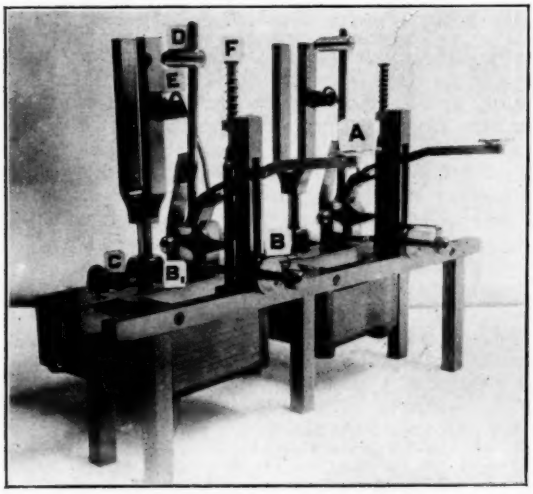


FIG. 2.—Automatic Tuning-Fork Hammers.

Since this apparatus is simply a double form of an instrument described in a previous article, detailed specifications

will be omitted.[3] The type of apparatus illustrated has the advantage of being more easily adapted to experimental investigations in which two successive stimuli, differing in pitch or in intensity, are required at short intervals. The essential features are: a key-rod (A) which depresses a slide (F) and momentarily releases the damper (E) while the fork is being struck. The hammer-piece (D) is engaged by means of a pawl by the slide in its downward movement and against the action of a tension-spring (seen to the right of B), whose tension can be regulated by a knurled nut (B). Near the point of extreme depression the hammer-piece is suddenly and automatically released. It strikes the tine of the fork with a force dependent upon the tension of the spring attached to its lower end. A clamp (C) is provided for holding the fork in place and is adjustable to fork-stems of varying thicknesses. The instrument serves very well for demonstrational purposes in large lecture-rooms and for investigational studies in the laboratory.

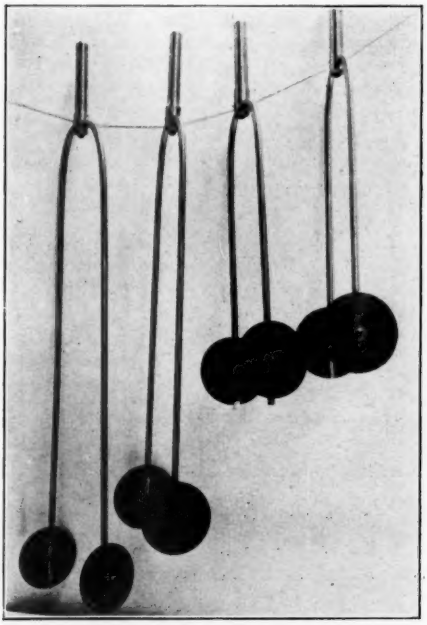


FIG. 3.—Adjustable Wire Forks.

[3] Bentley, M., Boring, E. G., and Ruckmich, C. A. New apparatus for acoustical experiments, *Am. J. of Psychol.*, 23, 1912, 515-516.

ADJUSTABLE WIRE FORKS.

A set of four wire forks has been made for the purpose of investigating the stimulus-limen for pitch, the relation of noise to tone, and analogous problems in acoustics. The four forks are uniform in construction; dimensions differ only in the length of tines and in the amount of their separation at the extreme ends. The tines of the two smallest forks measure 17 in. in length and are separated 5½ in. at the end; the tines of the next larger fork are 24 in. long and are separated 6 in. at the end; and the largest fork has tines 29 in. long and separated 6½ in. at the end. The tines of all of the forks are slightly divergent. They are made of ⅜ in. tool-steel with a handle of ¾ in. steel cut to a length of 5¾ in. A heavy pin and screw fasten the tines to the handle. Hard fibre discs, 3/16 in. thick and 3⅞ in. in diameter, mounted on the tines by means of adjustable brass thumb-screws, serve as riders and at the same time amplify the intensity of the vibratory disturbance. When permanently adjusted and calibrated, the total range of the forks will extend from 8 to 40 vd.

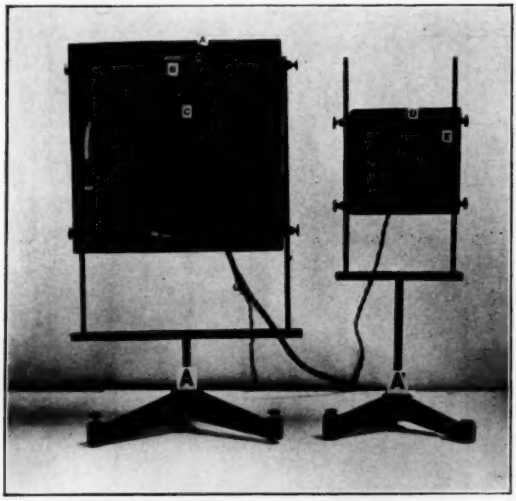


FIG. 4.—Blind-Spot Apparatus.

In connection with a doctorate thesis it became necessary to provide a reliable control of eye-movement. One of the

methods used in this research was the well-known procedure involving successive determinations of the position of the blind-spot. There was no standard piece of apparatus available by means of which this work could be quickly and accurately done. The requirements of the method were satisfactorily met by instruments which were constructed in the departmental machine-shop.[4] The apparatus on the left (A) is used to map out the blind-spot; the one on the right (A′) furnishes the fixation-point. The experiment is performed under dark-adaptation. The principal feature of the larger apparatus is a sheet-iron box 12 in. square and 6 in. deep, mounted by a set of four thumb-screws on a bracket and tripod 22 in. high. The box contains a 16 c. p. electric incandescent lamp fixed in the center of the door which forms the back. The front of the box carries a circular plate 12 in. in diameter. This plate is attached to the box by four broad rivets moving in slots which are cut into the plate in the form of an arc of 45 degrees (one of these arcs is to be seen just above B). The plate is rotated through this arc by means of two projecting handles. Two circular rows of eight discs are mounted on the plate, those in the outer row (B) measuring 2 in. in diameter with centers 3 3/32 in. from the center of the plate, those in the inner row (C) measuring 1⅛ in. in diameter with centers 1½ in. away from the center of the plate. The discs are provided with projecting flaps by means of which they may be rotated. A series of five holes is drilled in each of the larger discs, and a series of three holes in each of the smaller discs. These holes are located on concentric circles with 3/16 in. difference in radius and at points 22½ degrees of rotation apart. The holes are 3/32 in. in diameter. Behind the discs, drilled into the plate along each of four partial diameters that are spaced at angles of 45 degrees, there is a series of 32 still smaller holes corresponding exactly to the successive positions of the holes in the discs under which they lie. The light within the box is allowed to penetrate the holes in the plate only when the holes in the discs are made to correspond with them. Since each disc may be rotated 360 degrees, it successively uncovers double the number of holes that it contains. Furthermore, since the large circular plate may be rotated 45 degrees and since

[4] While the suggestions of members of the department are in large measure responsible for the original design of pieces of apparatus described in this article, Mr. Clayton F. Harding, the departmental machinist, has added other suggestions or has materially improved the original design in the course of construction. The department will undertake to supply any of the pieces described at prices which can be had on application.

the exact position of the plate may be determined from an engraved scale (barely seen to the right of small A), all points, located in a circular field of about 8 in. in diameter and at distances of 3/16 in. units from the center of the plate, can be investigated. The fixation-box (A′) in a like manner permits the adjustment of the fixation-point in the vertical and in the horizontal direction. The vertical direction is controlled by a sliding rod (D) and the horizontal direction by two discs 2½ in. in diameter. The holes are of the same diameter as those in the other box, are 3/16 in. apart, and number twelve in each direction in addition to the common central point. The box is also adjustable in the vertical plane by means of four set-screws on the side of the box; it is cubical in shape; and it measures 6 in. on each side. A 16 c. p. incandescent lamp is fastened inside the box. Both pieces of apparatus are finished in flat black on the outside and are enameled in white on the inside. They are provided with electric cord attachments for a 110 v. circuit; resistance may be introduced to avoid halos or pronounced after-images. Two set-screws are inserted in each tripod in order to give the boxes an absolutely vertical position.

The apparatus is set up a meter and a half from the observer's eye. His head is kept steady in a head-rest. After the fixation has been determined, the blind-spot apparatus is adjusted so that points are found that are just within the blind area. The distance between the blind-spot apparatus and the fixation-point apparatus is arranged to suit the requirements of different observers. When the apparatus is set for any one individual, the points thus determined naturally mark the areal extent of that observer's blind-spot at the distance mentioned. Whenever any one or more of these points become visible, other conditions[5] being equal, eye-movement is indicated.

DISC CUTTER.

An improved form of cutter, used in connection with experiments in color-mixture, in peripheral vision, and in any field which requires paper-discs of uniform sizes, has been built in the laboratory and has given satisfactory service. While it was built primarily for cutting paper-discs, with the exercise of care, thin cardboard may also be cut.

The base (F) consists of ½ in. cast-iron covered with 1/16

[5] These conditions include absolute fixation of the head, accurate and immediate report of the visibility of the spots of light, and the special factors which must be taken into account generally in investigations of the visual sensations.

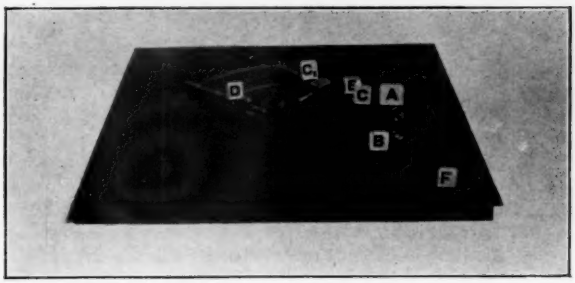


FIG. 5.—Disc Cutter.

in. soft brass which is fastened to the iron by means of six brass machine-screws. The base measures one foot square. The cutting-wheel (B) is made of tempered steel, one inch in diameter, and is protected by a knurled brass hood (A), ¾ in. wide. On the side which faces the base it is flattened to permit the projection of the blade on the surface of the paper. The hood is permanently screwed to the stem of the cutter to prevent rotation and consequent tearing of the paper. The pivot (E) is made of steel, 9/16 in. square, and contains on its lower surface a steel pin, ⅝ in. long and 3/16 in. in diameter, which fits into a steel die, mounted in the center of the base, measuring ½ in. in outside diameter, and projecting 3/16 in. above the surface of the base. On the upper surface of the pivot, a knurled brass thumb-screw is provided for adjusting the distance between the pivot and the cutting-wheel. This thumb-screw is about an inch in diameter and carries a pin which fits into a key-way on the upper surface of the cutting-stem. This also insures against the rotation of the hood (A). For purposes of rapid and accurate adjustment, two stops (C and C_1) are provided. These consist of brass collars that fit the cutting-stem. They are fastened with small knurled thumb-screws which project into the key-way on the stem. The two positions at which these stops are maintained correspond to the two sizes of discs commonly used in our laboratory, *viz.*, 11 cm. and 20 cm. in diameter respectively. The stem is graduated in centimeters to facilitate the process of adjustment. A center-punch (D) completes the outfit. The pointed end of this device fits into the steel die in the center of the base and the brass cup which is mounted on the stem is made just large enough to pass snugly around the outside of the die.

The cutting operations are as follows: (1) the sheet from which the desired disc is to be cut is placed on the base so that the circle, engraved thereon from previous cutting and therefore representing the desired size, is just within the limits of the sheet; (2) the position of the center-die is determined by a slight pressure with the thumb on that portion of the sheet; (3) the centre-punch is brought point down into the die to cut the hole and is then removed; (4) the cutting-tool, with its wheel adjusted at the proper cutting distance from the pivot, is inserted into the hole previously made, and is then revolved over the surface of the sheet.

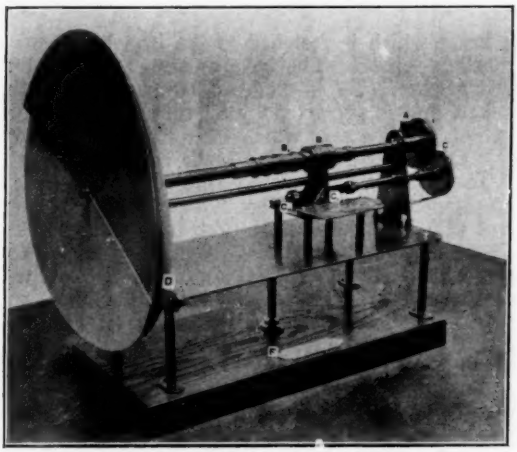


FIG. 6.—Variable Color-mixer.

This is a modification and enlargement of the Musil[6] color-mixer which, in turn, is an improved form of the Marbe mixer. With the larger construction naturally new problems of detail had to be solved, so while the principle is not entirely new, several of the important features are original. Reference to the diagrams which illustrate the Musil pattern will indicate the major changes.

The colored papers which represent the color-components to be mixed are mounted on cardboard to prevent ruffling

[6] Spindler and Hoyer, Psychological apparatus, Catalog No. 21, 1908, pp. 52-54.

and tearing. The diameter of the discs which the apparatus will carry is 16 in. The discs are slit in the usual way. On the flap nearest the machine a cardboard lip is attached and is inserted through a slit in the heavy backing behind the color-discs. An ordinary pin holds this securely in place. The backing and the attached color-disc are mounted on the inner axle of the machine. The other color-disc is attached by means of a clamp (D) to a balanced arm which projects from the outer axle or casing. Except when changes are made in the composition of the mixture, both inner and outer axles are rotated together with the pulley and shaft (A). This pulley is of brass, 3¼ in. in diameter; the shaft with its attachments is 23 in. in length. The steel inner axle is ⅝ in. in diameter; the outer brass casing is ¾ in. in diameter. Oil-cups and bushings are provided at both ends and at the end nearest the color-discs where the wear is greater, ball-bearings are located. To vary the mixture the large brass dial (C) is turned. The amount of change can be read on the face of the dial in units of a degree or fraction thereof. For convenience and accuracy a pointer indicates the exact position of the dial. As the dial is rotated, the steel stem, to which it is attached and which carries 11 threads to the inch, moves the carriage (behind C_1) along tracks on the platform (on either side of C_{11}). The carriage-arm is flanked by two ball-bearing collars (B) which are fastened to the casing containing the spiral key-way. The key-way makes one complete turn in 3½ in. of its length and is reënforced by three brass bands which encircle it. To prevent this casing from turning in relation to the inner axle, it carries a pin which travels in a straight key-way cut into the inner steel axle (between A and B). The outer axle with its casing attached to the variable color-disc is equipped with a lozenge-shaped pin which follows the spiral key-way. Since the casing which carries the spiral key-way cannot rotate with respect to the inner axle and its color-disc, the outer axle with its variable color-disc and casing must be the one to rotate in relation to the inner axle when adjustment is being made, because the pin which guides its movement is compelled to follow the spiral path as the casing which contains this spiral key-way is moved back and forth by the carriage-arm. By means of a pointer attached to the carriage, the platform (C_1) indicates samples of the colors which are being mixed and the respective amounts of the mixture in units of five degrees. The whole apparatus stands about a foot high on an oak base, 10 in. wide and 20 in. long, and is supported by five legs, the center one (F) being adjustable

to prevent the sagging of the large brass base-plate. The apparatus has been tested out with a 1/6 H.P. Emerson electric motor at a speed sufficiently rapid to prevent flicker and has been found serviceable for demonstrational purposes.[7]

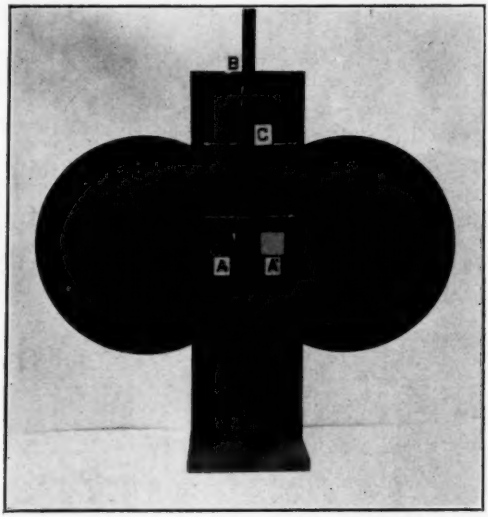


FIG. 7.—Apparatus for Paired Exposures.
(Front View)

This apparatus was built for the purpose of presenting a series of twelve colors according to the procedure of paired comparisons in the standardised form of the method of impression. It is used both for laboratory exercises and for demonstrational work.

On the side facing the observer (fig. 7) nothing is seen except the upright wooden frame 30 in. high and 9 in. wide at the base with two partial circles extending 12 in. on either side of the upright frame. When used in laboratory exercises, the experimenter raises the slide (fig. 7, B) and with it the attached shutter (fig. 7, just below C) by means of the handle (fig. 8, under B). If he finds it convenient, the

[7] The type of motor used automatically assumes the load only after its full speed has been attained.

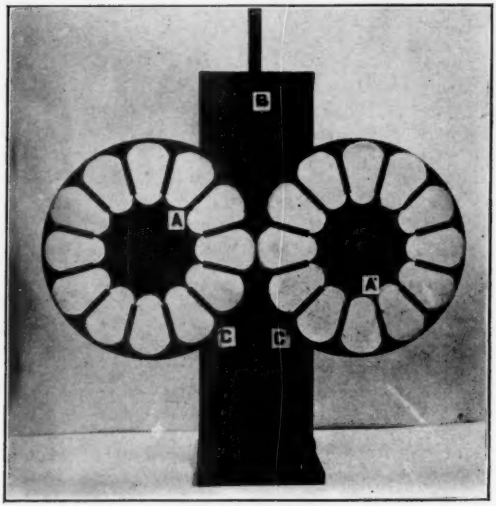


FIG. 8.—Apparatus for Paired Exposures.
(Rear View)

experimenter may set the pivoted end of the slide into a metal socket provided for the purpose of keeping the shutter open. The colored papers are then visible through the two apertures (fig. 7, A and A′), which are 2 in. square and 2 in. apart. The colors are changed by rotating the sheet-iron wheels (fig. 8, A and A′), which carry the papers in thin metal runways. A backing of cardboard serves to keep the papers flat and displays the number of the color in the series. Holes, 2¾ in. in diameter, are cut into the wheels opposite the apertures seen from the front (fig. 7, A and A′). To make certain that the colors are in their correct positions, notches are cut in the circumferences of the wheels to correspond to each successive exposure. A spring trigger (fig. 8, barely seen at C and C′) momentarily prevents further rotation. The apparatus is finished in dead-black. It is our experience that by means of this apparatus the papers are presented in a much more systematic fashion and are kept in better condition than in the process of ordinary manipulation.

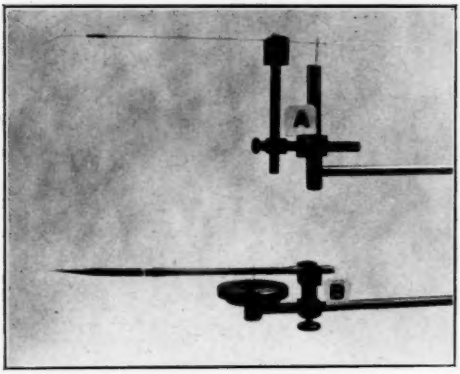


FIG. 9A.—Metal Piston Recorder.
FIG. 9B.—Demountable Tambour.

The principal improvement in this form of recorder lies in the fact that it is constructed entirely of metal; the pivots are of tempered steel, the recording arm is of aluminum, and the rest is of brass. Hence it has an advantage over the Lombard-Pillsbury form in that the irregularities of plaster and glass are avoided.[8] The cylinder, measuring 3 in. in length and ¼ in. in inside diameter, is carefully bored and ground out and accurately fits a small brass plate, less than 1/32 in. in thickness, which forms the piston-head. Into this plate is soldered a very light brass wire, 1½ in. long, and hooked at the end which enters the hole in the aluminum recording arm. This arm, 8 in. in length, is accurately balanced and carries on its farther end a short hog's bristle. The entire moving parts weigh 1.542 grams, or about four times the weight of the corresponding parts in the Lombard-Pillsbury recorder. Two small set-screws are provided to hold the pivots in position; the pivots are also adjustable.

While we have not yet tested the inertia and comparative accuracy of the recorder, several score trials have resulted in records that compare favorably with those made by the earlier models. The apparatus requires much less attention. For one thing, the need of constant lubrication and the consequent removal of accumulated oil is avoided. It is likely that further improvement will be made along the line of reducing the weight of the moving parts.

[8] Lombard, W. P., and Pillsbury, W. B. *Am. J. of Physiol*, 3, 1900, 186-200. Modifications of this form of recorder are described in Shepard, J. F., The circulation and sleep, 1914. p. 7.

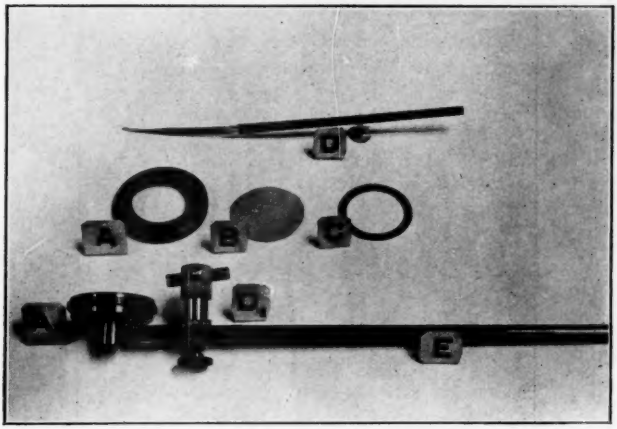


FIG. 11.—Demountable Tambour.

The chief advantage in this form of Marey tambour lies in the fact that the rubber dam is very readily renewed. The tambour is shown in both the assembled (fig. 9B) and in the unassembled state (fig. 11). The main parts are: (1) the writing-arm (D), 6½ in. long, made of an ordinary soda-straw, with a celluloid point attached by means of an aluminum band and with a bent celluloid bridge which rests on the rubber dam; (2) a knurled brass cap (A) which, after the rubber dam (B) and the washer (C) have been put into position, fits over the capsule (A_1) and holds the dam tightly over the capsule with an area of about an inch in diameter left free to vibrate; and (3) the stem (E) made of brass tubing 9½ in. long and ¼ in. in diameter, opening into the capsule and carrying the pivot (D_1) into which the writing-arm is inserted (as in fig. 9B). A half-inch knurled set-screw attaches the pivot-block to the stem and allows adjustment for writing-points of various lengths. Since the bridge is also adjustable, the same writing-point may be given greater or less length and consequent excursion on the drum.

ADJUSTABLE STANDARD.

A new pattern of adjustable standard has been constructed in the laboratory. The main adjustments are made by means of a thumb-screw (B), one inch in diameter, and a knurled nut (A), 1½ in. in diameter. The thumb-screw has a long

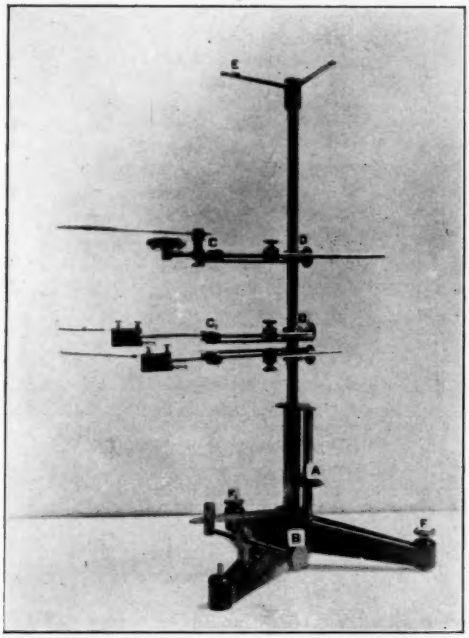


FIG. 10.—Adjustable Standard.

threaded stem which passes through a horizontal pivot-block inserted into one of the legs of the large cast-iron tripod. The stem has a total length of 5½ in. and a diameter of ¼ in., and carries twenty threads to the inch. On the opposite end from the head this stem is fitted into an arm projecting 5 in. from the center of the main shaft and fastened thereto. The shaft rotates on its vertical axis in obedience to the adjustments of the thumb-screw (B), and consists essentially of two parts: the upper, made of half-inch solid brass rod and telescoping into the lower in response to adjustments made by means of the knurled nut (A). The latter moves vertically on a stem, 4½ in. long and ½ in. in diameter, carrying 12 threads to the inch. In so doing it operates a ¼ in. pin with a roller bearing which travels in a groove deeply cut into the side of the nut. This pin is rigidly fastened into the telescoped portion of the upper shaft. A key-way is cut

into the side of the lower shaft facing the nut to allow the pin to move with the nut. The lower shaft is made of ¾ in. brass. The threaded stem is held in place by two horizontal projections 1½ in. from the center of the main shaft. As the nut is rotated, it moves up or down the stem and carries with it the upper portion of the standard to which the markers are attached.

Three arms are provided with the standard, two of them so arranged that they may be moved as closely together as the instruments carried will permit. The arms are constructed of ⅛ in. brass, as are all similar parts in the apparatus; they vary from 2¼ to ⅞ in. in width, and are 4⅝ in. long; and they are fastened to the upper shaft of the standard by ⅞ in. set-screws which travel in a key-way cut in the shaft (D and D_1). A half-inch collar is attached to the arm to give sufficient body to the thread for the set-screws. A block is provided for attaching the markers or writing devices. This is one-half inch high and ¾ in. in diameter, and has a ⅜ in. hole drilled horizontally through it. The required device is inserted into this hole, is fastened by means of the set-screw inserted from the top, and is permitted side-play by virtue of the slight rotation of the block on the arm. At the outer end of the arm (C and C_1) is a set-screw, 1½ in. in length, which carries a loose concave plate at the end of its stem. Operating against this plate is a similar one backed by a compression spring on a sliding rod, 1½ in. long. The writing device is inserted between these plates and can be adjusted toward or away from the kymograph-drum by turning the set-screw.

At the top of the shaft, two additional legs are attached so that the standard may also be used in the horizontal position. These legs are 4¼ in. long, ¼ in. in diameter, and are attached to a movable sleeve at an angle of about 60 degrees with one another. The standard is made almost entirely of brass, stands at an average height of 24 in., and can be adjusted in the vertical position by two set-screws mounted in the tripod (F and F_1).

Wall-Charts

A series of twenty-five charts, appropriate for use in the lecture-room and in the laboratory, has been prepared under the direction of the department. The charts were made by means of a compressed air-brush in the hands of the University Artist.[9] About one-half of them are tinted in colors;

[9] Requests for further information concerning these charts may be addressed to the Department of Psychology, University of Illinois, or to the artist, Mr. Charles W. Redwood, Forestry Bldg., Cornell University.

the rest are in black and white. The material used was water-color on heavy 'elephant paper' with cloth backing, 42 in. in width and from three to five feet in length. They were prepared ready for hanging with a strip of molding on each end.

Appended is a list of these charts; they are numbered in Roman notation. The Arabic numbers refer to the separate figures on the chart. There is a brief description and a citation of the source from which the chart was copied in each instance.

I. Organ of Audition.
  1. Semicircular canals in cochlea.
     From a stereopticon slide: photographic reproduction of a plaster model.
  2. Modified diagrammatic transection of right ear.
     After Czermak.
  3. Diagrammatic transection of a whorl of the cochlea.
     Foster, M. A text-book of physiology, 1891, vol. 4, fig. 177, p. 203.

II. Organ of Corti.
  1. General transection of the organ of Corti in the cochlea of a new-born pig.
     Shambaugh, G. E. *Arch. of Otol.*, 37, 1908, plate xiv, fig. 2, opp. p. 457.
  2. Similar transection showing bloodvessel under basilar membrane.
     Ibid., fig. 4.
  3. Similar transection to show the attachment of the membrana tectoria to hair-cells.
     Shambaugh, G. E. *Zeits. f. Ohrenhlk.*, 62, 1910, Taf. x, Abb. 2 (reversed), opp. p. 235.
  4. Transection similar to 3, to show attachment to outer hair-cells.
     Ibid., Abb. 5.

III. Analyses of complex Sound-waves.
  1. Graphic analysis of irregular, periodic, longitudinal vibrations into simple, regular, periodic, sinusoid vibrations.
     Wundt, W. Grundzüge der physiologischen Psychologie, 6th ed., 1910, vol. 2, fig. 171, p. 70.
  2. Graphic analysis of complex sound-wave into waves corresponding to a simple tone with an additional simple tone of double vibration-rate and of less intensity.
     Ibid., fig. 172(A), p. 72.
  3. Graphic analysis of complex sound-wave into waves corresponding to a simple tone with an additional simple tone of triple vibration-rate and of less intensity.
     Ibid., fig. 172(B), p. 72.

IV. Graphic representation of Vocal Sounds, showing irregular wave-structure.
  1. German vowel ā at c (= 128 vd.)
     Ibid., fig. 245(1), p. 396, after L. Hermann.
  2. German vowel ō at c (= 128 vd.)
     Ibid., fig. 245(2), p. 396, after L. Hermann.

3. German vowel ū at c (= 128 vd.)
   Ibid., fig. 245(3), p. 396, after L. Hermann.
4. German vowel ē at c (= 128 vd.)
   Ibid., fig. 245(4), p. 396, after L. Hermann.
5. German vowel ī at g (= 192 vd.)
   Ibid., fig. 245(5), p. 396, after L. Hermann.
6. German pronunciation of 'ibba' at g (= 192 vd.)
   Ibid., fig. 246(7), p. 399, after L. Hermann.
7. German pronunciation of 'ikki' at e (= 160 vd.)
   Ibid., fig. 246(8), p. 399, after L. Hermann.

V. Difference Tones.
   Schema of the primary difference tones with reference to the interval of the generating tones within the octave.
   Krüger, F. *Arch. f. d. gesam. Psychol.*, 1, 1903, 272.

VI. Circle of Complementary Colors.
   Hering's theoretical schema of the four primary colors and their resultant mixtures.
   Hering, E. Lehre vom Grundzüge der Lichtsinn, 1905, opp. p. 42; also in Graefe-Saemisch Handbuch, 2nd ed., pt. 1, chap. 12, and in Myers, C. S. A text-book of experimental psychology, 2nd ed., 1911, pt. 1, plate i, fig. A, opp. p. 89.

VII. The Retina and Visual Theory.
   1. Section of the retina.
      Lickley, J. B. The nervous system, 1912, p. 92.
   2. Graphic representation of the Hering components of color-vision as distributed over the visual spectrum.
      Ibid., p. 99.

VIII. The alleged migration of Retinal Pigments.
   1. Distribution of pigment-bodies during light-stimulation.
      Nagel, W. Handbuch d. Physiologie d. Menschen, 1905, vol. 3, Taf. i, opp. p. 94.
   2. Distribution of pigment-bodies before light-stimulation.
      Nagel, W. Handbuch d. Physiologie d. Menschen, 1905, vol. 3, Taf. i, opp. p. 94.

IX. Miscellaneous Organs of Sense.
   1. Olfactory receptor-organ in left nasal cavity.
      Lickley, J. B. *op. cit.*, p. 113.
   2. Olfactory receptor-cells.
      Ibid., p. 113.
   3. Longitudinal and transverse section of a Meissner corpuscle in cutaneous tissue of the hand (cutaneous pressure).
      Ibid., p. 117.
   4. Gustatory organs in papilla foliata.
      Ibid., p. 115.
   5. Gustatory organs in gustatory pore and taste-bud.
      Ibid., p. 115.
   6. End-bulb of Krause in cutaneous tissue (cold).
      Ibid., p. 117.
   7. Pacinian corpuscle (subcutaneous or muscular pressure).
      Ibid., p. 118.
   8. Nerve-ending of Ruffini (warmth).
      Ibid., p. 117.
   9. Spindle of Golgi in tendon (tendinous strain).
      Ibid., p. 119.

X. General view of demonstrational Rhythm-hammer (Cornell pattern).
Illustrating device for demonstrating temporal perceptions.
Bentley, M. *Am. J. of Psychol.*, 23, 1912, fig. 4, opp. p. 514.

XI. Cathedral Perspective.
Shows architectural curve in pillar to produce illusory exaggeration of height as viewed from the floor.
Goodyear, W. H. *Memoirs of Art and Archaeology* (Museum of Brooklyn Inst. of Art and Sciences), 1894, vol. 1, no. 4, p. 26.

XII. Dioptrics of the Stereoscope.
A dioptric diagram in colors illustrating the principle of the Brewster stereoscope.
Simplified from Titchener, E. B. Experimental psychology, 1901, vol. 1, pt. 2 (Instructor's manual), fig. 66, p. 268.

XIII. Synaesthesia: chromaesthesia.
Illustrations representing vowel, consonant, number, and word associations with colors.
Galton, F. Inquiries into human faculty, etc., 1883, plate iv, fig. 69, after p. 380.

XIV. Synaesthesia: number-forms.
Illustrating the association of numerical series with diagrams.
Galton, F. *Op. cit.*, plates i, ii, iii, figs. 1. 2, 7, 8, 9, 10, 20, 27, 37, 56, 59, after p. 380.

XV. The Expressive Method as applied to Emotion.
Fig. 1-3. Sthenic type of emotion expressed by curves representing breathing (above) and blood-volume, pulse-rate, and Traube-Hering waves (below).
1. Transition from pleasurable thought of successful work to unpleasurable thought of fatigue at 'a'.
Wundt, W. *Op. cit.*, 5th ed., 1903, vol. 3, p. 228.
2-3. A continuous curve representing strong anger induced by memory of heated argument. At first pulse is depressed (unpleasantness). Depression increases with continued emotion. Breathing is strengthened, shortened, and irregular.
Ibid., p. 229.
4. A curve representing momentary and depressing emotion of sudden fright. Decrease of volume and pulse, and irregular breathing.
Ibid., p. 230.

XVI. Plan of Reaction Experiment.
Disposition of apparatus and electrical connections in the typical simple reaction experiment requiring the Hipp chronoscope and accessory instruments.
Wundt, W. *Op. cit.*, 6th ed., 1911, vol. 3, fig. 368, p. 366.

XVII. The Human Brain.
1. Adult type of fissuration, female, 29 yr., dorsal aspect, rich in gyres.
Retzius, G. Das Menschenhirn, 1896, vol. 2, plate 54, fig. 2.
2. Adult type of fissuration, male, 37 yr., dorsal aspect, poor in gyres, but unusual in type.
Ibid., plate 54, fig. 1.

3. Ventral aspect, showing cerebellum, male, 48 yr.
Ibid., plate 60, fig. 1.
4. Lateral aspect of left hemisphere, showing left aspect, male, 36 yr.
Ibid., plate 64, fig. 1.
5. Median section of cerebrum, showing median aspect of left hemisphere, male, 50 yr.
Ibid., plate 67, fig. 2.

XVIII. The Earthworm.
1. General view.
Parker & Haswell, Text-book of zoölogy, 1910, vol. 1, p. 454.
2. Anterior segments.
Ibid., p. 454.
3. Sagittal section through anterior half.
Ibid., p. 457.
4. Central nervous system.
Ibid., p. 459.

XIX. Internal view of Earthworm.
Stereographic representation of the circulatory, digestive, and nervous systems in the middle segments (in color).
Original sketch by Redwood, *et al.*

XX. The Nervous System of the Earthworm.
1. Longitudinal section showing peripheral nervous system: cord and setae.
Lenhossék, M. von, *Arch. f. mikros. Anat.*, 39, 1892, Taf. v, fig. 6.
2. Free nerve-endings in epidermis.
After Smirnow.
3. Transection of cord showing neuronic connections.
Lenhossék, M. von, *op. cit.*, Taf. v, fig. 10.

XXI. Sense-organs of the Earthworm.
1-2. Visual cells.
Hesse, R., *Zeits. f. wiss. Zoöl.*, 61, 1896, Taf. xx, fig. 6b, 14.
3-6. Sense-organs in epidermis (chemical).
Langdon, F. E., *J. of Morph.*, 11, 1905, plate xiii, fig. 1, 4, 11, 2, opp. p. 232.

XXII. Discrimination-box (University of Illinois model).
Cf. Watson, J. B., and Yerkes, R. M., Methods of studying vision in animals, *J. of Animal Behav., Monog. Supp.*, I, no. 2, 1911, 18.
1-3. Showing side, top, and general views, respectively.

XXIII. The Animal Maze (University of Illinois standardisation).
General top view of the model, 5 ft. 2 in. in diameter, showing detention-box and wire-cover in additional diagrams.

XXIV. Ant-nest (University of Illinois modification of the Janet-Fielde nest).
Combined top and side view of the plaster-model, 16¼ in. x 5¾ in., showing the four compartments and openings for the extraction or insertion of ants.

XXV. The Salivary Reaction of the Dog (Pavlov's method).
Diagrammatic representation of the disposition of apparatus in connection with the expressive method as applied to the dog.
Yerkes, R. M., and Morgulius, S., *Psychol. Bull.*, 1909, 6, 264. *V.* also Watson, J. B., Behavior, 1914, p. 66 (after Nicolai).

NOTES ON PRACTICE, IMPROVABILITY, AND THE CURVE OF WORK

By Edward L. Thorndike,
Teachers College, Columbia University

Learning and the Curve of Work in the Case of a Clerical Task

Sixty-four educated adults practiced writing the products of 11 x 11, 11 x 12, 12 x 12, 11 x 13, ... 19 x 19 with the aid of a key as shown below.

	11	12	13	14	15	16	17	18	19
11	121	132	143	154	165	176	187	198	209
12	...	144	156	168	180	192	204	216	228
13	...	...	169	182	195	208	221	234	247
14	...	...	...	196	210	224	238	252	266
15	...	...	...	...	225	240	255	270	285
16	...	...	...	...	...	256	272	288	304
17	.....	...	...	...	...	...	289	306	323
18	...	...	...	...	...	...	...	324	342
19	...	...	...	...	...	...	...	...	361

The subject wrote as rapidly as possible the products of 80 pairs of numbers printed in a haphazard order as shown below, using the Key or trusting to memory. The time of beginning and ending and the number of mistakes were recorded. The time record was as exact as the subject could make it, using an ordinary watch with a second hand.

17	19	18	19	11	16	17	17	12	12
12	11	15	18	14	17	12	18	13	14
14	16	16	19	15	19	13	15	14	19
19	11	18	12	16	17	16	12	15	13
18	18	12	13	15	16	18	15	16	11
15	11	17	18	18	14	19	16	18	13
16	18	11	12	13	16	16	13	11	17
13	19	19	18	17	12	14	18	17	14
12	17	15	14	11	13	16	16	13	11

13	13	19	13	14	15	15	17	18	16
18	11	14	11	19	19	16	14	14	14
19	17	11	19	16	15	14	13	15	12
15	15	17	15	19	14	18	17	17	16
19	12	13	18	13	17	12	19	11	14
12	14	14	12	12	15	17	13	13	12
17	11	19	15	11	18	11	15	12	16

Four different sheets, of 80 pairs each, were used in rotation, each one twelve times, making forty-eight sheets done or 3840 entries. The distribution of the practice differed in different groups of subjects, being according to the following scheme:

	Number of sheets done per sitting	Number of sheets done per day	Number of subjects
The 2.2 group	2	2	9
" 2.4 "	2	4	11
" 2.8 "	2	8	10
" 2.8_1 "	2	8 every other day	10
" 8.8 "	8	8	9
" 8.8_2 "	8	8 every other day	15

The practice was preceded and followed by a test with a still different sheet of 50 pairs.

The Nature and Amount of Improvement

The improvement consisted in a mixture of memorizing the products, complete or partial, becoming acquainted with the arrangement of the key and skillful in using it, facility in reading the pairs, facility in entering the products and facility in what may be called "overlapping"—perceiving the next pair and beginning to look at the key or think of the remembered product while entering the product for the previous pair. In no case did the learning progress to complete and perfect memorizing of all the 45 products. No such case was reported, and the shortest times (1.33 sec. and 1.45 sec. per pair) are too long for perfect memorizing.

The improvement is, as would be expected, universal and large. The central tendency is to do twice as much per unit of time and with half as many errors, in the last four sheets of the forty-eight as in the first four. The gain from the preliminary test with 50 pairs to the final test is still greater.

The Effect of the Distribution of Time Upon Improvement

In order to compare the effect of the different distributions of practice it is necessary to equalize the initial ability of the groups by subtracting one or more cases. When this is done,

we have, as average scores with the first four sheets, average scores with the last four sheets, average gross gains and average corrected gains, the following:

	Average score with sheets 1-4		Average score with sheets 45-48		Average gross gain		Average corrected gain, counting each error as 10 seconds
	Secs.	Er'rs.	Secs.	Er'rs.	Secs.	Er'rs.	
2.2 (n 9)	1506	4.66	733	2.00	773	2.66	800
2.4 (n 10)	1531	4.10	750	3.20	781	.90	790
2.8 (n 7)	1523	3.57	809	3.57	714	00	714
2.8½ (n 8)	1478	7.75	814	1.88	664	5.87	723
8.8 (n 9)	1492	8.22	764	3.22	728	5.00	778
8.8½ (n 15)	1517	4.13	760	2.40	757	1.73	774

Taking these results at their face value, they show (1) that when 8 sheets are done daily or every other day, they are more profitably done 8 at a sitting than 2 at a sitting, (2) that whether practice is daily or every other day makes little or no difference in the improvement per unit of time spent, and (3) that whether practice is spread over 24 days or consolidated into 6 makes little difference provided the long day's work is done at one sitting.

The individual differences in improvement are, however, very large and the correction for errors is rather arbitrary, so that the quantities should be considered in combination with similar quantities found in other studies rather than alone. So considered, they seem to support the doctrine that in such minor clerical tasks as adding, substitution tests, hunting for items and the like, there is little or no advantage in very short periods of learning, but is some advantage in fairly long intervals between practice, other things being equal.

Individual Differences in Improvement

Individual differences in improvement are large. The extremes for the total group are represented by (1) individual H. G. C., who worked the first four sheets of the forty-eight at a rate of 18.7 pairs per minute, and the last five sheets at a rate of 45.0 pairs per minute, spending in all 6967 sec., or 6237 sec. from the mid-point of the first four to the mid-point of the last four, and (2) individual Whi., who worked the first four at a rate of 7.93 pairs per minute, and the fourth four at a rate of 9.6 pairs per minute, spending so far 8440 sec., or 6230 sec. from the mid-point of the first four to the mid-point of the fourth four. The use of the four sheets' average is a little unfair to Whi., but this is balanced by the

fact that his errors increased from 0 to 9 whereas those of H. G. C. decreased from 3 to 1. H. G. C. and Whi. then, from equal amounts of time given to practice, made gains of 26.3 and 1.7 respectively, in the product produced per unit of time.

The rate of gross gain in the product produced per unit of time is, as I have elsewhere shown, positively correlated with initial ability.

The facts for groups of high and low initial ability are shown below.

	Average number of minutes from beginning to end of the practice measured here	Average number of pairs per minute in 4 sheets	Average number of pairs per minute in 4 sheets done after about 122 minutes of practice (from mid-point to mid-point)	Gain in pairs per minute	Average number of errors in first four	Average number of errors in late four
8 initially highest individuals.....	134½	19.4	34.6	15.2	3.38	4.63
4 initially next highest individuals ...	146	16.3	29.9(131 min.)	13.6	5.5	2.8
7 initially next to lowest individuals.	161	11.4	20.8(133 min.)	9.4	5.14	3.71
5 initially lowest individuals.....	155½	7.87	12.56	4.7	8.5	5.6

The effect of equalizing opportunity is thus to increase individual differences. This result, now found with many different functions, furnishes perhaps the strongest argument in support of the view that differences in achievement are largely due to differences in original capacity.

The correlation between initial ability and improvement is, of course, not perfect, fairly large differences in the latter being found amongst those of equal initial scores. Thus Br. and H. G. C., beginning at 18.5 and 18.6 pairs per minute respectively, gained 13.5 and 26.3, though the former spent more time than the latter. Thus Me. and Ch., beginning at 16.6 and 16.3, gained 7.0 and 20.8 respectively, though the former spent much more time than the latter.

Changes in the Rate of Improvement

The form of the practice curves in so short an experiment as this is not of much theoretical importance. It is in general

of a type beginning with notable negative acceleration and passing thence into an approximately straight line, the form being roughly as in Fig. 1.

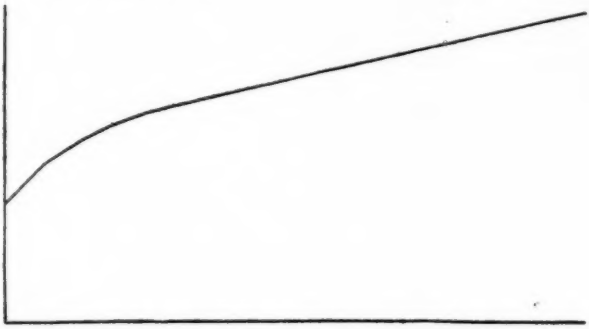


FIG 1.—The approximate form of the curve of practice in recording the products of pairs of numbers from a key.

THE CORRELATION BETWEEN SPEED AND ACCURACY

The total time spent and the total number of wrong products entered for each individual in 12 selected sheets are shown in Table I. This correlation table shows that there is a positive relation, and that in particular, no one of the twelve most rapid workers was amongst the dozen or so most inaccurate workers. The correlation between speed and accuracy by the formula $r = \text{cosine } \pi U$ where U is the estimated percentage of the unlike-signed pairs, is somewhat over $+.4$.

THE CURVE OF WORK

We may use the records for those individuals who did eight sheets at a sitting for an analysis of the curve of work. In this I have utilized only the records of the last thirty-six or twenty-four sheets, so as to examine the function after it is well established.

When no allowance for errors is made, the average time required for the successive sheets of a sitting stood in the following relation: 108.3, 104.1, 99.5, 101.3, 98.7, 98.2, 96.2, 93.8. The P. E.'s (or median probable divergences of these quantities from the similar quantities obtained from an infinite number of similar experiments) are, in order: 1.5, 1.9, .9, .5, .5, 1.3, 1.3, .8. When 10 seconds is added for each

TABLE I

Correlation Between Speed and Accuracy

Time required for 960 products: In minutes: 39 = 39.0 to 41.0, 41 = 41.0 to 43.0, etc.

Errors made in 960 products	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81	83	85	87	89	91	93
1– 3	..	..	..	1	..	..	..	1	..	1	1	..	1	1	..	1	..	..	..	..	..	..	..	..	..	..	..	..
4– 6	..	..	1	..	..	1	1	1	1	3	1	..	1	..	..	1	2	..	..	..	..	..	..	1	..	..	..	1
7– 9	..	..	1	..	1	2	1	2	..	2	1	2	1	..	1	..	1	..	..	1	..	..	..	..	..	..	..	..
10–12	..	..	..	..	..	..	..	2	1	4	..	1	..	2	2	1	..	..	1	..	..	..	..	..	..	..	..	..
13–15	1	..	..	1	1	1	1	1	2	..	..	2	..	1	4	3	..	..	1	..	1	..	..	1	..	..	..	..
16–18	..	..	..	1	..	..	1	1	..	1	1	..	2	1	1	..	1	..	..	..	..	..	..	..	..	..	..	..
19–21	..	..	..	..	..	..	2	1	..	..	..	1	2	1	..	..	..	..	..	1	..	1	1	..	..	..	..	..
22–24	..	..	..	..	1	..	..	1	1	..	2	..	1	1	2	..	..	..	..	1	..	..	..	..	..	..	..	..
25–27	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1	1	..	1	..	..	..	..	..	..	..	..	..
28–30	..	..	..	..	..	..	1	..	..	..	..	..	1	..	1	..	..	2	..	..	..	..	..	..	..	..	..	..
31–33	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
34–36	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
37–39	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..
40–42	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..
43–45	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..
46–48	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
49–51	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..
52–54	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
55–57	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
58–61	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..

error the average corrected times for the successive sheets of a sitting are in the relation: 107.8, 103.4, 98.4, 100.8, 99.1, 96.9, 96.7, 93.8. The P. E.'s for these quantities are, in order: 2.2, 2.2, 1.5, .5, .6, .9, 1.1, 1.3. In terms of product produced per unit of time these quantities appear as in Fig. 2 and Fig. 3.

There is thus no evidence of "initial spurt" and very slight evidence of "end spurt." The case is no different if only those individuals who took three minutes or less per sheet are used. The curve of work is substantially a section of the latter part of the general curve of learning plus perhaps a slight "warming up" effect and a still slighter "end spurt." The irregularities toward the middle of the curve are, in my opinion, most probably a matter of accidental variation.

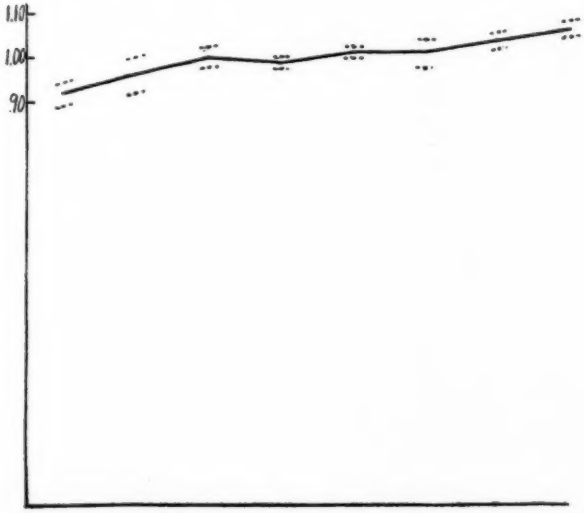


FIG. 2.—The curve of work for recording the products of pairs of numbers from a key. Equal lengths along the abscissa represent equal numbers of sheets done. The height of the continuous line represents the time required, as a multiple of the average time required for sheets IV and V. The dotted lines are at a distance from the continuous line equal to 2 P.E.

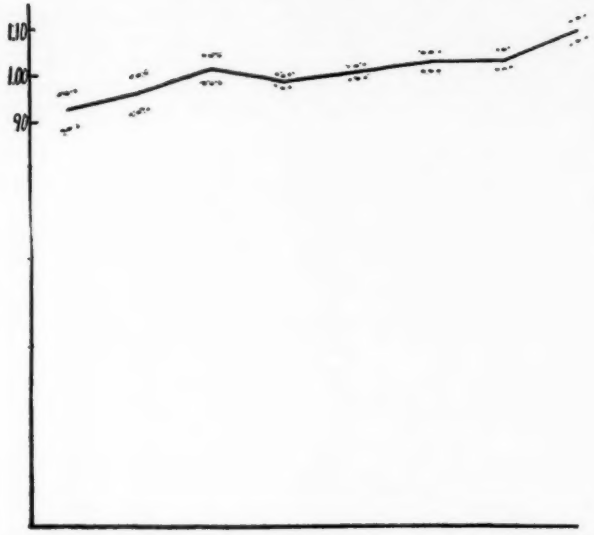


FIG. 3.—Same as Fig. 2 except that an addition of 10 sec. for each error is made.

The Correlations Between Initial Ability and Improvement and Between Improvement and One Function and Improvement in Other Functions.

Fifteen college students practiced on each of five days for each of two weeks at checking numbers on the Woodworth-Wells blank, adding columns of figures, multiplying mentally with two three-place numbers after the method used previously by the author, and typewriting. The details concerning the length of periods, the conditions of practice and the like need not be reported here. They were free from anything prejudicial to the conclusions to be stated here.[1]

The data used are shown in Table II. The six lines reported for each individual concern the results in canceling 2's

[1] The practice occurred in connection with the work of the New York State Commission on Ventilation made possible by the Anderson foundation, was planned by the author and was carried on under the immediate direction of Mr. W. A. McCall. For the computations required for this article the author is responsible. Full details concerning the experiments may be found in VENTILATION IN RELATION TO MENTAL WORK by Thorndike, McCall and Chapman, New York, 1916.

(first line), canceling 3's (second line), addition (third line), mental multiplication (fourth line), and typewriting (first ten minutes in the fifth line and second ten minutes in the sixth line). The figure under 'Average' in the case of line 6 is, however, in each case, the *median* of the four scores of lines 5 and 6.

TABLE II

INITIAL AND FINAL SCORES OF 15 INDIVIDUALS

		Day 1			Day 10			Gain in Day 1 to Day 10
		Trial 1	Trial 2	Average	Trial 1	Trial 2	Average	
Brdd....	2's...	134	146	140	174	166	170	30
	3's...	150	152	151	186	176	181	30
	Add.	94	113	104	151	149	150	46
	Mult.	50	68	59	100	98	99	40
	Typ.	155	166		222	205		
		132	158	157	219	183	212	55
Ferg.	2's...	132	134	133	164	162	163	30
	3's...	132	132	132	158	162	160	28
	Add.	62	79	71	122	131	127	56
	Mult.	44	37	41	90	86	88	49
	Typ.	61	77		141	144		
		78	82	78	133	151	143	65
Leik.	2's...	120	130	125	154	156	155	30
	3's...	142	138	140	180	156	168	28
	Add.	63	69	66	95	99	97	31
	Mult.	69	122	96	173	143	158	62
	Typ.	80	89		150	141		
		80	95	85	153	145	148	63
Levy....	2's...	94	110	102	136	154	145	43
	3's...	98	124	111	148	142	145	34
	Add.	40	44	42	60	70	65	23
	Mult.	31	57	44	109	113	111	67
	Typ.	71	86		141	124		
		77	92	82	145	135	138	56
Bost....	2's...	104	106	105	200	196	198	93
	3's...	124	124	124	176	176	176	52
	Add.	38	43	41	58	67	63	22
	Mult.	68	96	82	282	279	281	199
	Typ.	120	147		240	237		
		128	139	134	220	206	229	95
Elle.....	2's...	108	108	108	195	202	199	91
	3's...	108	118	113	143	166	155	42
	Add.	74	75	75	123	105	114	39
	Mult.	67	80	74	226	250	238	164
	Typ.	205	189		242	230		
		198	191	195	223	229	230	35

TABLE II—*Continued*

INITIAL AND FINAL SCORES OF 15 INDIVIDUALS

		Day 1			Day 10			Gain in Day 1 to Day 10
		Trial 1	Trial 2	Average	Trial 1	Trial 2	Average	
Solo.	2's	134	140	137	190	198	194	57
	3's	144	150	147	196	182	189	42
	Add.	63	68	66	122	113	118	52
	Mult.	89	113	101	161	164	163	62
	Typ.	59	114		170	160		
		104	130	109	177	195	174	65
Kuen	2's	110	112	111	152	158	155	44
	3's	122	126	124	138	142	140	16
	Add.	53	50	52	97	108	103	51
	Mult.	82	80	81	192	188	190	109
	Typ.	76	86		139	133		
		75	80	78	126	137	135	57
Rivl.	2's	118	122	120	184	188	186	66
	3's	138	136	137	172	168	170	33
	Add.	49	44	47	106	114	110	63
	Mult.	40	47	44	179	200	190	146
	Typ.	95	118		155	161		
		101	123	110	153	174	158	48
Stac.	2's	88	106	97	154	166	160	63
	3's	126	128	127	162	164	163	36
	Add.	79	88	84	128	124	126	42
	Mult.	65	82	74	218	212	215	141
	Typ.	39	53		125	147		
		50	66	52	125	145	135	83
Zuck.	2's	104	114	109	140	160	150	41
	3's	122	126	124	160	152	156	32
	Add.	53	59	56	113	110	112	56
	Mult.	71	107	89	323	342	333	244
	Typ.	84	86		162	169		
		71	85	85	160	165	164	79

Except in the case of typewriting, the gain in product produced per unit of time is a little greater for those of initially high ability. In typewriting, the opposite is the case. This is what would be expected in view of the form of the curve of practice in typewriting, and the fact that the amount of practice one has had in it is largely independent of his ability.

The data of Table I give some information concerning the relation of ability to improve in one mental function to ability to improve in other functions. The correlations by the formula $r = 2 \sin \left(\frac{\pi}{6}\rho\right)$ where $\rho = 1 - \frac{6\xi D^2}{N(n^2-1)}$ are:

Gain in canceling with gain in adding.....r =.10
" " " " " " mental multiplication.....r =.29
" " " " " " typewriting.....r =.10
" " adding with gain in mental multiplication.....r =.25
" " " " " " typewriting.....r =.12
" " mental multiplication with gain in typewriting...r =.07

These correlations are subject to attenuation but not to any large extent, the correlation between the gain in canceling 2's and the gain in canceling 3's being .77, that between the gain in addition (trial 1) and gain in addition (trial 2) being .84, that between gain in mental multiplication (trial 1) and between gain in mental multiplication (trial 2) being .81, and that between gain in typewriting (first period) and typewriting (second period) being .80. It is unlikely that these 15 subjects would then with perfect measures of gain show correlations over 20% higher than the raw correlations given above. We may estimate these corrected coefficients as:

Gain in canceling with gain in adding.....r =.12
" " " " " " mental multiplication.....r =.35
" " " " " " typewriting.....r =.12
" " adding with gain in mental multiplication.....r =.30
" " " " " " typewriting.....r =.14
" " mental multiplication with gain in typewriting...r =.09

The probable errors due to the small number of cases are of course large, approximating .15, but it must be remembered that further cases would be as likely to decrease as increase the correlations.

The capacity to learn thus appears to be specialized in much the same way as the abilities found at any stage of learning. The lack of correlation found among the latter is not the result chiefly of differences in the relative amounts of practice which they have had, but is in very large measure more fundamental, due to characteristics of the person's original nature.

The Effects of a Day of Study and a Night of Rest Upon the Ability to Read

It is desirable to repeat the experiments that have been made upon the effects of work and rest, using ordinary tasks instead of the special work in computation, memorizing and the like, which, tho convenient for measurement, may be specially stimulating by its novelty or by the obviousness of its standards of achievement.

As one such experiment, I have used the task of reading a paragraph and answering questions about it. Twelve para-

graphs, N, O, P, Q, R, S, T, V, W, X, Y and Z, were used, Z being shown here as a sample. They differed in difficulty, some being much harder than Z; and some, easier. Twelve individuals read these paragraphs and answered these questions, beginning work at or near 8 P. M., doing ten as a continuous task, and doing two more the next forenoon after a full night's rest. One individual did them in the order, N, O. P. Q, etc.; another in the order O, P, Q, R, etc.; another in the order P, Q, R, S, etc., so that each paragraph was done as the first, the second, ... the twelfth.

Z

Write your name here .....

Read this paragraph and then write the answers to questions 1, 2, 3 and 4. Read it again as often as you need to.

Certain anthropologists have been led to the conclusion that the types of human culture represent an evolutionary series; that the primitive tribes of our times represent an older stage of cultural development through which the more advanced types passed in earlier periods. An important theoretical consideration has shaken our faith in the correctness of the evolutionary theory as a whole. It is one of the essential traits of this theory that, in general, civilization has developed from simple forms to complex forms, and that extended fields of human culture have developed under more or less rationalistic impulses. Of late years we are beginning to recognize that human culture does not always develop from the simple to the complex, but that in many aspects two tendencies intercross,—one from the complex to the simple, the other from the simple to the complex. It is obvious that the history of industrial development is almost throughout that of increasing complexity. On the other hand, human activities that do not depend upon reasoning do not show a similar type of evolution. It is perhaps easiest to make this clear by the example of language, which in many respects is one of the most important evidences of the history of human development. Primitive languages are, on the whole, complex. Minute differences in point of view are given expression by means of grammatical forms; and the grammatical categories of Latin, and still more those of modern English, seem crude when compared to the complexity of psychological or logical forms which primitive languages recognize, but which in our speech are disregarded entirely. On the whole, the development of languages seems to be such that the nicer distinctions are

eliminated, although it must be acknowledged that opposite tendencies are not by any means absent.

1. In what feature is the development of man's work with tools contrasted with the development of his work with words? .....

. . . . . .

2. According to the doctrine that the different ways of living of different tribes of men form a progressive developmental series, what is the relation of simplicity and complexity to the temporal order of this developmental series? .....

. . . . . .

3. What principle of development is almost universally characteristic of the history of industry for the past ten thousand years or more? .....

. . . . . .

4. In what feature of civilization do primitive tribes seem to show greater elaborateness and delicacy of distinctions than modern Europeans? .....

. . . . . .

The time spent, the wrong answers given and a rough estimate of the satisfyingness of the work in each period, were recorded. 5 was used for an ordinary condition of enjoyment of work; 10, for the maximum of satisfyingness that an individual had ever experienced; 0, for the extreme of distaste and wretchedness.

The total times (in minutes), errors, correct responses, and reported satisfyingness at each period were as follows:

EVENING AFTER WORK

Period	1	2	3	4	5
Time	211.0	150.3	133.6	143.5	142.3
Errors	14	16	20	8	15
Correct responses	51	49	45	57	50
Satisfyingness	69	72.5	69	74	71.5
Period	6	7	8	9	10
Time	160.5	131.5	137.5	163.5	160.0
Errors	17	15	17	10	16
Correct responses	48	50	48	55	49
Satisfyingness	68.5	69.5	68.5	68	64.5

	Next Day, After Rest	
Period	11	12
Time	129.0	117.3
Errors	17	14
Correct responses	48	51
Satisfyingness	77.5	75.5

The time for the first paragraph read is long, the individual adapting himself to the task and being specially cautious. After that the times increase slightly. If we call the average time for periods 2, 3, and 4, 100, that for periods 5, 6 and 7 is 101.6; and that for periods 8, 9 and 10 is 105.4. After the rest the time falls, being 84.5 on the basis of 100 for periods 2, 3 and 4. How much of these differences is to be credited to the eyes and how much to the central nervous system, remains a question. It is the writer's opinion that the major share belongs to the former. The quality of the work remains closely the same throughout, the errors for periods 2, 3 and 4 being 44; those for periods 5, 6 and 7 being 47; those for periods 8, 9 and 10 being 43; and those for periods 11 and 12 after rest being 31 (or 46½ on a just basis of comparison). The satisfyingness falls off as work progresses and increases sharply after rest. The average degree of satisfyingness in periods 2, 3 and 4 was 6.0; in periods 5, 6 and 7 it was 5.8; in periods 8, 9 and 10 it was 5.6; after rest it was 6.4.

The Effect of Rests Upon Achievement and Improvement in Difficult Mental Work

The form of work used in the experiments to be reported here was the mental multiplication of a three-place number by a two-place number, 1's or 0's being excluded from the digits of the numbers. The numbers themselves were visible throughout the multiplication. Five such examples were done without any pause save that required to write the answer, note the time at which it was written and record it. At the end of such a series of five, another series was begun either (a) at once, or (b) after 10 minutes of rest, or (c) after 20 minutes of rest. This, continued for five series or 25 examples, made one day's task. The score was the time for each example plus one-fifth of the time for each wrong figure in the answer. This was understood by the subjects and they were instructed to work for the best attainable score.

The subjects were divided into three squads, each of which did 25 examples on each of three consecutive days and 5 examples in the morning of the fourth day. Squad 1 (11 individuals) worked the first day with 0 rests, the second day

with 10-minute rests and the third day with 20-minute rests. Squad 2 (7 individuals) worked the first day with 10-minute rests, the second day with 20-minute rests, and the third day with 0 rests. Squad 3 (8 individuals) worked the first day with 20-minute rests, the second day with 0 rests and the third day with 10-minute rests.

To prevent the very slow individuals from having undue weight in determining the conclusions, I have expressed each individual's scores as a per cent of his average score for the entire sixteen series (of 5 examples each). When this is done and the results for each squad are averaged, we have the following results:

	Day 1					Day 2					Day 3					Day 4
Squad 1	153	140	145	151	113	99	97	92	84	76	71	73	90	83	84	61
Squad 2	140	128	127	126	109	94	99	97	88	95	82	83	91	82	84	76
Squad 3	163	145	129	138	97	102	104	100	89	87	87	82	73	71	69	62

When the gains are put in relation to the length of the rest periods, the results, as shown below, favor slightly the 10-minute rest periods, both in immediate achievement and in the effect as it remains over twenty-four hours. It would be of interest to discover whether the 10-minute periods would be equally effective if filled with some other variety of work. The difference over 0 rest is not sufficient to justify the rests as periods of inactivity in practice.

GAINS FROM THE FIRST TO THE FIFTH SERIES OF THE SAME DAY

	Day 1	Day 2	Day 3	Sum
With 0 rests.....	40	15	—2	53
" 10' "	31	23	18	72
" 20' "	66	—1	—13	52

GAINS FROM THE FIRST SERIES OF ONE DAY TO THE FIRST SERIES OF THE FOLLOWING DAY

	Day 1 to 2	Day 2 to 3	Day 3 to 4	Sum
With 0 rests.....	54	15	6	75
" 10' "	46	28	15	89
" 20' "	61	12	10	83

It may be noted that the average curve of the work of all three squads shows substantially no effect of the 24-hour intervals. Those intervals, under the conditions of the experiment, in which they were filled by the student's ordinary activities and sleep, did as much good as they did harm by the remission of the special activity. The final day's test, either because of

the special rest before it, or because of the facilitation due to knowledge that it was the last of the series, or for both causes, was much better than the last series of the day before.[2]

The results of this experiment are consistent with all similar experiments in showing a very rapid improvement in the special function concerned, such as could not occur if the chief element in the efficiency of the function were a general power of 'concentration' which the previous lives of the subjects had improved *in toto*.

The experiments give useful data concerning initial spurt—a general tendency to maintain for a minute or so a rate of achievement which is soon abandoned. I have compared the scores for the first, second and third examples in a series after rest in the case of the eight most rapid workers, the result being an average time of 77 sec. with .426 wrong figures for the first, 94 sec. and .603 wrong for the second and 82 sec. and .441 wrong figures for the third. With six individuals who required two to three minutes per example, the averages for the first, second and third examples of a series after rest were, respectively, 128 sec. with .68 wrong figures, 138 sec. with .84 wrong figures and 141 sec. with .84 wrong figures. The superiority of the work of the first minute or two is not surely due to a general tendency to initial spurt, since a part of the difficulty of this mental multiplication is the confusion of the numbers with memories persevering from previous examples, a form of interference from which the first example of a series is obviously relatively free. In general, I have failed to find evidence of initial spurt in mental work.

[2] 152, 138, 134, 138, 106, interval, 98, 100, 100, 84, 86, interval, 80, 79, 85, 79, 79, special interval, 66.

MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF CORNELL UNIVERSITY

Communicated by E. B. TITCHENER and H. P. WELD

XXXII. ON CUTANEOUS AFTER-IMAGES

By F. L. DIMMICK

In 1897 F. H. Spindler published the results of experiments on "after-sensations of touch."[1] The irregularity of these results led us, in the following year, to repeat and extend the experiments. The experimenter was Mr. J. H. Wilson, a senior in psychology; the observers were Drs. T. L. Smith and G. M. Whipple, and Messrs. H. O. Cook, W. B. Secor, and W. H. Standring, seniors in the department. Eight weights, of 50 to 1000 gr., were applied to the skin for 5, 10 and 15 sec. Our results were in substantial agreement with those of Spindler. We found evidence, however, both objective and subjective, that the principal cause of irregularity (aside from crudeness of technique) was the response of *two* sensitive tissues (skin and underlying muscle) to the stimuli employed. *Two* after-sensations of different course and quality seem to be intermingled in this "after-sensation of touch"; and neither Spindler's original method nor the improved form of it used by Wilson enables us accurately to distinguish the two components. It has, accordingly, not seemed worth while to publish Wilson's results in detail.

Meantime M. H. S. Hayes has made a much more thorough study of the after-sensations from cutaneous stimulation.[2] As a stimulus for "punctiform" pressure, she used "rounded wooden points 1/32 inch in diameter, and von Frey hairs. These were applied, in the usual way, upon pressure spots which had been located and marked several days previous." Whether the intensity of the stimulus employed was above the limen for subcutaneous pressure does not seem to have been considered. For this reason we have repeated the work upon isolated pressure spots, using a stimulus whose intensity is known to be below the limen for subcutaneous pressure. This stimulus was the hair of a von Frey hair-aesthesiometer (length, 39 mm.; diameter, 0.18 mm.; force, 0.405 g.; tension value, 4.5 gr./mm.). The skin of the fore-arm was lightly anaesthetized; and it was found that, although the stimulus was well above the limen for the normal skin, no sensation was aroused during the anaesthesia. The aesthesiometer was applied by means of a mechanical device, which we hoped would ensure constancy and accurate timing of the stimulation. The essential parts of this device consisted of a wooden plunger working in a brass cylinder. From the side of the plunger extended a horizontal arm, which worked vertically in a slot in the cylinder. The arm carried a clamp in which the aesthesiometer was held. The apparatus was so supported over the arm of the observer that it could be moved in both directions in the horizontal. An electrical circuit was made at the instant the stimulus was applied and broken when it was removed. The observer reacted

[1] Psych. Rev., iv., 631ff.

[2] Psy. Rev. Mon. Sup. 60, 1912.

by pressing a key; and both records were written alongside of a 10 per sec. time line.

Method.—The observer was comfortably seated, with his right arm extended and resting upon a felt cushion. At his left hand was the reaction-key. He was told that his arm would be stimulated by a hair, and was instructed to hold down the key so long as he felt anything at the place of stimulation. The record showed the length of time during which the stimulus was applied, the point at which the observer felt the stimulus, the point at which he ceased to feel it, the point of arousal of the after-image (if there were an after-image), and its duration. After every stimulation the observer gave a brief introspective report of his experience. Ten pressure spots on the forearm of each observer were stimulated. These were marked by clipping away all the hairs in the region of stimulation except those at the bases of which the chosen spots lay. Only one intensity of stimulus was used. The time of stimulation was approximately 1 sec. Two observers took part in the experiments: G. J. Rich (R), and R. H. Cobb (C), both graduate students in psychology. About twenty series were taken with R, and fifteen with C.

Sources of Error.—(1) The times of stimulation were taken by a stop watch, and were not absolutely constant. A record of the exact times was kept, and the variation was found to be in the neighborhood of 12%. (2) Although every pressure spot was localized within an area of less than 1 mm., it was impossible to be certain that stimulation within that area would always produce the same impression. This uncertainty is borne out by the introspections. (3) Adaptation of the pressure spots was avoided by stimulating each one only once at a sitting.

Results.—The quantitative results for the two observers are given in the following tables.

TABLE I

OBSERVER C—69 CASES

Spot	Total Response A.Sn.+Int.+A.Im.	M.V. of A.Sn.	Int.+A.Im.	M.V. of Int.	A.Im.	M.V. of A.Im.	Report of Observer: Tickle	Report of Observer: Pressure (No Report)
1	10.88	(1.56)	8.61	(0.76)	7.66	(3.55)	5	2
5	9.92	(2.36)	6.55	(1.24)	5.26	(1.47)	2	3
6	9.54	(0.69)	8.53	(0.74)	7.37	(2.99)	5	2
4	8.72	(0.54)	7.48	(0.51)	6.75	(1.98)	3	4 (1)
8	8.68	(0.70)	7.10	(0.48)	6.48	(1.24)	6	3
2	8.54	(0.57)	7.31	(0.35)	6.58	(2.15)	3	2 (2)
3	7.17	(0.49)	6.27	(0.89)	5.37	(2.14)	2	6 (1)
7	7.06	(0.18)	6.43	(0.05)	6.22	(1.74)	0	5
10	6.72	(0.2)	5.94	(0.49)	5.30	(1.68)	0	4 (1)
9	6.48	(0.56)	5.10	(0.4)	4.50	(1.34)	2	4 (1)
	Av. A.Sn.	M.V.	Av. Int.	M.V.	Av. A.Im.	M.V.		
Summary.....	1.44	(0.15)	0.78	(0.57)	6.15	(2.18)	28	35 (6)

TABLE II

OBSERVER R—71 CASES

(I) 53 Cases

Spot	Total Response A.Sn.+ Int.+A.Im.	M.V. of A.Sn.	Int.+A.Im.	M.V. of Int.	A.Im.	M.V. of A.Im.	Report of Observer: Tickle	Report of Observer: Pressure
6	87.34	(12.62)	70.99	(1.8)	62.64	(13.3)	1	3
2	81.45	(13.72)	58.00	(2.91)	50.50	(8.0)	1	3
7	73.76	(11.03)	62.75	(3.4)	56.49	(11.9)	0	9
10	68.83	(18.64)	47.80	(4.2)	38.50	(16.7)	1	2
4	65.70	(0.47)	63.90	(2.9)	60.30	(22.7)	0	3
3	59.56	(1.14)	55.79	(3.7)	47.56	(25.4)	0	6
9	50.97	(9.7)	46.56	(3.6)	39.34	(18.9)	1	9
1	42.95	(3.79)	38.63	(2.91)	34.72	(19.9)	4	1
5	39.08	(2.7)	33.68	(1.67)	30.40	(20.2)	2	1
8	38.34	(14.0)	27.33	(5.6)	21.63	(10.3)	1	5
Summary..	Av. A.Sn. 11.41	M.V. (10.45)	Av. Int. 6.7	M.V. (3.7)	Av. A.Im. 44.39	M.V. (19.44)	11	42

II. 18 Cases

Spot	A.Sn.	M.V.					T	P
5	97.6	(31.1)	.....	.....	.....	.....	1	1
6	86.9	(38.5)	.....	.....	.....	.....	0	3
9	84.8	(0)	.....	.....	.....	.....	0	1
4	65.9	(35.2)	.....	.....	.....	.....	2	2
2	65.7	(19.5)	.....	.....	.....	.....	1	3
1	58.7	(0)	.....	.....	.....	.....	1	0
8	43.5	(23.2)	.....	.....	.....	.....	0	2
7	20.6	(0)	.....	.....	.....	.....	0	1
Summary..	66.7	(28.32)	.....	.....	.....	.....	5	13

That the After-Image is the most important of the moments is evident from the fact that the order of magnitude of the After-Image follows almost exactly that of the Total Response. There are only two bad inversions for R (spots 2 and 4), and one for C (spot 5), and these occur where there is an especially high M. V. for After-Sensation or Interval or both. The orders of magnitude of the other two moments do not follow that of the Total Response.

Observer R reported pressure in a large percentage of cases and tickle in comparatively few, whereas C reported tickle in nearly half of his observations.

The times for R are very much longer than those for C. The ratios between the three moments, however, are very nearly the same for both observers; and the times of all three moments for R are nearly 8 times as long as those for C. These ratios are given in the following tables.

TABLE III

Ratios	Obs. C.	Obs. R.
Latent interval / After-sensation	0.528	0.587
After-image / After-sensation	4.27	3.89
After-image / Latent interval	7.884	6.625

TABLE IV

Ratio	After-sensation	Latent Interval	After-image
Obs. R. / Obs. C.	7.9	8.5	7.2

Conclusions.—The results we have obtained seem to agree roughly with those of Hayes, though her findings are not given in a form that permits of direct comparison. Our results show the same wide variation for each observer and between observers; and the ranges of variation are approximately the same. We found the after-sensation always present. After-images were reported in a much larger number of cases than by Hayes. This difference may be due to the difference in the stimulus employed. Whether the relation which we have found between our two observers appeared in Hayes' work it is impossible to tell, but her "quantitative individual tables" indicate that an observer's times were either all long or all short.

XXXIII. On Perceptive Forms below the Level of the Two-Point Limen

By E. de Laski

It is clear from the results obtained by Gates [1] and Titchener [2] that certain of the perceptive patterns which occur below the level of the cutaneous two-point limen are sufficiently stable for quantitative determination. It seems desirable that the whole range of these patterns [3] be systematically explored, and the present paper records a first beginning of such exploration.

[1] E. J. Gates, The Determination of the Limens of Single and Dual Impression by the Method of Constant Stimuli, this Journal, xxvi, 1915, 152ff.

[2] E. B. Titchener, in *Proc. Amer. Philos. Soc.*, lv, 1916, 208ff.

[3] For the patterns in general see M. Foucault, L'illusion paradoxale et le seuil de Weber, 1910, 124f.

The work was done during the Summer Session of 1916. The stimuli were applied by an improved Jastrow aesthesiometer to the volar side of the right arm. A line about 8 cm. in length was marked longitudinally upon the skin, beginning at a point about 2.5 cm. above the wrist; veins and hard tissues were avoided. The points were set down at different parts of this line. (It may be said at once that the area of stimulation was too large; both observers complained that the perceptive patterns varied from part to part of the line. It is better to adopt a smaller area, and to prevent fatigue by taking the observations slowly.) The observer's arm was fixed in a rest, and the aesthesiometer was applied by hand. The observers were Dr. J. N. Curtis, and Mr. F. L. Dimmick, assistant in the department.

The plan of work was as follows. Two stimuli, below the two-point limen, were chosen, and were given with knowledge in a practice-series of 10 to 20 observations (usually the same number for each stimulus). The observer was to memorise the perceptive forms and to give them names. Thereafter the experiment proper was performed: haphazard series were made up of 20 terms (10 of each stimulus), and the observer was required to name the forms as they occurred. In all cases but one, the blunt point formed by apposition of the aesthesiometer-points was used as one member of the stimulus-pair. We hoped to compare with one another all the separations employed, but lack of time forbade. The order in which the experiments were taken is shown in the following tables; the total number of judgments indicates roughly the difficulty of establishing the particular form under observation.

OBSERVER C

Stimuli	Total number of judgments	Number of Errors: With lesser stimulus	Number of Errors: With greater stimulus	Per cent accuracy	Maximal per cent accuracy in a single series
App., 40 mm.	40	..	..	100	100
App., 25	160	29	20	69	85
App., 20	20	0	2	90	90
App., 15	120	14	20	72	80
App., 10	280	54	56	61	85
10, 20	140	20	19	72	85

In the first five of these experiments C judged in terms of *line* and *spot*. The *spot* was "a fairly round one with a hard place in the middle (deep, thick place)." The 40 mm.-pattern was a line with several points in it. The remaining *lines* were of the dumb-bell kind: "a vague oval with foci quite prominent and a tight little line connecting the foci." The patterns in the sixth experiment were distinguished merely by the length of this connecting line. C's patterns were, unfortunately, blurred by the shift of the stimuli along the 8 cm.-line of stimulation; she sometimes felt additional points within (or beyond?) the dumb-bell. The distribution of errors is, nevertheless, fairly regular.

OBSERVER D

Stimuli	Total number of judgments	Number of Errors: With lesser stimulus	Number of Errors: With greater stimulus	Per cent accuracy	Maximal per cent accuracy in a single series
App., 30 mm.	120	13	23	70	95
App., 25	20	3	1	80	80
App., 20	60	10	7	72	85
App., 15	220	33	29	72	95
App., 10	200	22	29	75	95

In all these experiments D judged in terms of *long* and *blunt*. The latter he described as "a pressure both cutaneous and subcutaneous, a blurry shapeless spot, dull." The *longs* varied from indefinite ovals to "just a larger and more blurry mass, perhaps greater in pressure than the blunt." D was usually fatigued at the time of the experiments, and the fatigue seems to have affected the definiteness of his reports, though not his numerical accuracy. He complained, as C did, of the change of pattern with shift of stimulation. The distribution of errors is, again, fairly regular.

Conclusions.—It seems certain that subliminal separations of the aesthesiometer-points are discriminable. This result has an obvious bearing upon the determination of limens.

Discrimination appears to be based not upon length (quantitative) but upon form (qualitative); for the percentage of accuracy does not vary with the difference between the two stimuli. Moreover, we do not find any progressive effect of practice.

The introspective reports also point to the conclusion that perceptive form is the basis of judgment. C remarked, incidentally, that repetition fatigued her, and was a hindrance rather than a help.

This preliminary work shows that the stimuli should be applied (1) within a small area, (2) with light pressure, and (3) with fairly long time-intervals (perhaps 40 to 50 sec.) between the stimulus-pairs.

We have still to determine whether the perceptive forms constitute a series, and if so whether the series is continuous or discrete; and to work out the number of just noticeable differences between the perception of 'spot' or 'point' and the two-point limen.

IS INTROSPECTION INDIVIDUAL OR SOCIAL, WITHIN OR WITHOUT?

By W. D. Wallis, University of California

When Mr. McDougall assures us[1] that all psychology is built up on analogy with the psychologist's mind, he provides no means for ascertaining whether our individual psychology happens to represent that of a normal individual. His method would give us not a psychology, but psychologies as numerous and erratic as individual minds. The ideal that rests anywhere rests nowhere.

Mr. McDougall's scientific spirit shows that he means other than he says, and that by the individual mind with which he starts he means a mind of a certain type. Indeed, he himself admits this. "Before we can give an adequate account of the individual," he says, "we must be able to describe in general terms the innate basis of the mind, in so far as it is common to all men."

If this be the key to the situation, it is the type which is important, the individual mind being of value as the basis for a psychology only in so far as it conforms to this type. If this be admitted it follows that introspection is of value, not for its uniqueness, but because it expresses conformity to a type of mind external to the introspector. He must, first of all, ascertain whether his own mind is normal; and this he cannot do unless he have already the norm by which his own mind is to be standardised. Without a common norm psychologists will scarcely find a fulcrum for their aggregate efforts or reason to hope for harmony in procedures and results, beyond the consolation that pure chance may favor their ardent efforts—a coincidence so wonderful that it could be regarded only as a law not yet understood.

How can introspection give us type of mind, seeing that such introspection is but a way of finding out whether we are of the posited type? To be valid it must be controlled by a logic from without, the logic that we apply to other minds and they, in turn, apply to us.

A priori, we have no more assurance of our own mentality than of the mentality of another; self and own mind are correlatives implying other and other minds. Even the search for our own mentality implies a mentality other than that of the searcher.

An uncontrolled introspection can be nothing else than haphazard and resultless. The introspective error can be corrected only when the within is correlated with the without. Until introspection is removed from the realm of unique individual insight and made part of an inclusive system of external tests we have no accepted criterion, no uniform method. We must think into ourselves, not look into ourselves. A looking which is not a thinking provides no corrective for its illusions. If we apply an objective test, the unique advantage which an individual has with regard to his own experience is supplemented with an opportunity to view himself as would an outsider, and to apply a rigid standard over and above the elastic introspective analysis. After all, it is

[1] Psychology (Home University Library). He is following orthodox psychology.

the outside world that leads a man to a knowledge of his self rather than a knowledge of his self that gives him a grip upon the outside world.

If his mentality be part of an integral interrelated system, analysis might begin at any part of the system and proceed to any other part of it; for if the self is given meaning by reason of the world the world is given meaning by reason of the self.

The society of which the individual is a part even in his introspective moments is not far to seek. So far as he succeeds in taking the position of an outsider and in objectifying his mental content he makes of himself an observer and of his self as observed a society; for observer and observed have no meaning unless there is some third mind for which both may be object of observation.

The external social world is part of this larger self and claimant for the ascendency. To it every personality must give heed. But not in the same way. For this social world, too, may be objectified. Once objectified it may claim the ascendency, or it may be subordinated to some purpose higher than the social, to a purpose comprising both the social and the individual. The external social world must, first of all be inherited, in order to play its rôle. It must be accepted and affirmed by the individual in order that he may respond to its beck and call. In order to be an external world of compulsion the world without must become part of the world within. And once it has been placed within it may be reorientated in the individual's system of values and transformed in the light of his purposes. The outside world is part of the individual if he is really a part of it.

BOOK REVIEW

Digest of "Alcoholism and Mental Depression." By Dr. PIERRE JANET. Read August 7, 1915, before the Academy of Moral and Political Sciences, Paris, as published in *Revue Internationale de Sociologie*, October, 1915.

Despite the many studies of Alcoholism the envisagement of the subject is not yet complete. The major portion of these studies have to do with alcohol, and against its production and consumption legal measures are proposed. But this is superficial symptomatic treatment rather than etiological. It is necessary to study the alcoholic and his malady in order to attempt a cure. It is a difficult subject, one to be approached with pity and compassion for the unfortunates.

Psychologically the alcoholic is more than a drinker of alcohol,—not a mere drunkard. Intoxication or inebriation is a rapidly developed disturbance of normal thought and conduct by absorption of alcohol,—an abnormal state produced in a normal individual. The alcoholic on the contrary does not become inebriated; he is an individual who has need of alcohol to become normal, yet he may know well the danger he runs in trying to satisfy this craving, as well as the expense he incurs and the family suffering he causes. He resists and promises family and friends to quit, but to no avail, though he seek medical assistance to quit. He fails to quit simply because the demand for the drink exceeds his resistance powers. Therefore we may define an alcoholic as one who needs alcohol to become normal and with whom this need is irresistible.

Whence this need and why its irresistibility is the true moral problem of alcoholism. An incident taken from my medical experience quite accurately depicts the case. A young physician of forty years, in the last stages of alcoholism, gave to me the history of his terrible passion for alcohol:

"From my youth," said he, "I was subject to a very painful malady. Occasionally, every year or two years, I fell into a state of profound melancholy and for several months would become incapable of doing things, of speaking, and especially of making decisions. The smallest act demanded extraordinary and painful efforts. I suffered keen moral torture because of a terrible contempt for myself and a feeling of moral shame. It seemed I had become the lowest of men and would befoul any place I entered. One can scarcely imagine what one suffers in such a state. I had in vain tried various treatments. One day a group of students sought me out at one of those worst moments and took me to a university fête They dragged me along and forced me to drink almost in spite of myself. The result was extraordinary. After heavy consumption of alcoholic drinks I was not inebriated but felt myself becoming more and more normal. The veil which had covered my head was rent; it seemed as though I was reborn, that I began a new life. I was again able to talk and act, and my feeling of happiness became as exaggerated as had previously been the feeling of shame. I returned home without trouble, and was able to digest and to sleep as I long had not been able to do. I awoke cured. It was inevitable that

when the horrible melancholy began again some days later that I hurriedly sought the remedy, at first with curiosity, then with frenzy. I have never since been able to check myself."

Such cases can be multiplied; and this same evolution is met in the development of other impulsions towards drugs,—opium, morphine, and even to flight, but above all to drink.

The initial pathological condition is a state of mental depression. There is no destruction or disturbance of function or faculty but simply that these functions or faculties remain in potential state without culminating in action. The old psychology was static, describing faculties *per se* and seemed to take it for granted that because a faculty existed it was able to functionize. An advancement of psychology, especially in mental diseases, is that it has become dynamic, and concerns itself more with the functionizing of faculties and with what I have previously termed *psychological tension.* The degree of this tension or the elevation of the mental plane depends not upon the number of tendencies possessed by the individuals but upon the number and degree of perfection tendencies which find fruition in functionizing. The oscillations of this tension have great importance. They explain not only a large number of mental diseases but the wide variations of sleep and sleeplessness, rest and fatigue, as well as the emotions, which are all variations of the psychological tension.

Depression is a lowering of the psychological tension much below that necessary for adaptation to the environment of the individual. This depression determines a host of very curious phenomena, of impotency of action, especially of the higher and more complex ones, of agitations, of horrible feelings of abasement, and of desperate efforts to escape this state.

Opposed to these depressions there is in these oscillations another essential phenomenon,—excitement. Excitement is essentially a rapid elevation of the psychological tension; it admits of the inversed phenomena of the precedents, that is to say, of the acts of adaptation rightly performed, and of tranquillity. The faculties functionize without distress, painful feelings make way to pleasurable ones, and there is joy, interest, confidence, independence.

The absorption of certain substances, certain poisons, among which alcohol is the best known, produces excitement. Alcoholic excitement occurs even with the normal individual, but is not very remarkable and is of short duration, because the psychological tension already high is susceptible of small heightening before drunkenness ensues. But with the depressed individual excitement raises the psychological tension to the normal level. Alcohol which disturbs speech and prevents sleep in the normal man restores speech to the timid depressed one and restores sleep to the insomnolent. Alcohol thus delivers the depressed one from horrible torture, and when he relapses puts before him temptations incomprehensible to the normal individual.

It cannot be said this is dipsomania, and not common alcoholism. Too often we make this distinction. They are of the same genus in which are many varieties. Dipsomania has been distinguished because of the periodicity of the depression. These alternations are absent in the alcoholic. Chronic depressions, light or profound, are more common than one might suppose, at least for some years, which produce by the same mechanism as does dipsomania a need for exciting drink.

It is easy to show that alcoholism and mental depression originate in the same conditions. Individuals who for years resist the temptation to drink even in the midst of it will often become alcoholics following

an infectious disease, typhoid fever or light attack of tuberculosis, just as one becomes depressed following physical or mental overwork, or following a change of surroundings, a quarrel, a disappointment in love, etc. Alcoholism acts as do all impulsions of the depressed, it diminishes with simple and easy life and augments with the higher and more trying activities. Alcoholism, like dipsomania, is a consequence of depression. I may say without here being able to demonstrate, that the same is true of that other great scourge of France, depopulation. I have reached a conclusion which may appear strange; it is that a people who alcoholize themselves, and who have no more children, is a people attacked by a sort of collective mental disease, a very general mental depression. Infectious diseases, intoxicants, alcoholism of parents with its circle of vicious results, unwholesome habitations, undernourishment, factory life, all doubtless play important rôles. Overwork, especially mental overwork peculiar to our epoch plays a chief rôle. Philosophical ideas as to equality of men have leveled ambitions. That our system of higher education is not entirely blameless is shown by numberless pathological observations. It is a delicate subject; but let me suggest: Formerly mental tension was not high and rested in beliefs quite agreeable and easy. We now repeatedly say that everybody should apply reason to his beliefs and accept as true only what seems evidently such. This is very right and beautiful; but do all little garcons have the intellect of Descartes? This is not to condemn or regret the progress of democracy or the liberty of thought, but it is to say that they are difficult and costly advancements, paid for by overwork and depression.

Placing alcoholism and even depopulation as a result of profound mental disturbances and depression caused by a diminution of vitality and overwork should not cause us to despair of applying successful therapeutics. Alcoholism must be combatted by reducing it and rendering the use of alcohol difficult. The legal measures are good if courageously enforced; but such is difficult. Selfish interests group around alcohol and these combat the enforcement of legal measures to reduce alcohol consumption. The unfortunate alcoholics themselves because of their suffering will continue to intoxicate themselves.

Besides, it is a question if the suppression of alcohol will cure the disease. Ordinarily the suppression of one excitant simply forces the diseased to seek another. We might well regard with distrust opium, cocaine, and other powerful excitants.

We have heard discussion of the excellent results of the suppression of alcohol in Russia. In medical practice things do not happen so simply. Great emotions, great dangers, energetic acts greatly heighten the courage of depressed individuals, and war is a great excitant. At this moment there are fewer depressed in Paris than under normal conditions and many ordinarily depressed maintain themselves on a superior plane. Hence the suppression of alcohol is more easily tolerated than in calm periods. We should profit by the occasion and accept the unique benefit of a horrible war. This is the time or never to suppress absinthe, alcohol, cabarets, distilleries, and obtain quickly when it will pass unnoticed this suppression which will not obtain later without great opposition and suffering.

But this alone will not suffice. Legal steps against alcohol are but symptomatic therapeutics the complete success of which would be only contingent. Some day we must go further and deal with the fundamental evil,—mental depression. We must deal with the social (the most essential) aspects of the problem not alone with the legal. Better

housing conditions, cleaner air, are factors in the therapeutics of depression and alcoholism. Sufficient nourishment of workmen and the advancement of popular hygiene promise much.

Besides physical hygiene some day we will concern ourselves with moral hygiene. In conserving social advancement overwork must be prevented. To diminish social conflicts and rapid aspirations for equality and dangerous ambitions, to inspire a certain respect for authority and reconcile the irreconcilable, liberty of thought and tranquillity of belief, these are problems closely associated with that of alcoholism and depopulation.

The advancement of psychological and social sciences will one day formulate the rules of this special hygiene of the mind and the academy of moral sciences will then be the great council of moral hygiene. In the meantime do not despair. Individual depressions frequently yield to treatment,—those of the people may be cured also.

Independence, Missouri. FREDERICK M. SMITH.

BOOK NOTES

Evolution and the war. By P. CHALMERS MITCHELL. London, John Murray, 1915. 114 p.

This is a brilliant and original book by a well-known biologist. He discusses war and the struggle for existence, this latter struggle among animals, nationality and race, the production of a nationality, and selective factors, the foundations of nationality, with epigenetic features. The main feature of the book is its rather radical denial of the existence or at least the importance of psychic heredity. Part of it he thinks is due to suggestion and that if people never knew the traits of their progenitors they would often never develop them. The very fact of educability suggests that man is far more plastic to develop in individual directions, quite apart from his ancestry, than animals are. He would not perhaps say the mind is a *tabula rasa,* but all kinds of possibilities are open. He holds that consciousness transforms all qualities and faculties acquired by human beings from the animal world, and that is the foundation of free and intelligent existence. He holds Kant responsible for what he calls "the dreaming megalomania that has destroyed the German sense of reality and has made German *Kultur* the enemy of the human race." Nietzsche was only a terminal flower of this poisonous and sterile idealism. Bernard Shaw is "only Nietzsche grinning through a horse collar." As against Darwin he urges "that the moral law is as real and external to man as the starry vault. It has no secure seat in any single man or any single nation." It is not inborn but inherited from traditions and customs in literature and religion. Its creation and subsistence is the crowning glory of man and his consciousness of it puts him in a high place above the animal world. The struggle for existence, therefore, does not apply to man. Modern nations are not units of the same order as the units of the animal and vegetable kingdom from which the law of the struggle for existence is a supposed inference. Dar-

win's struggle has no analogue in human welfare. Man is not subject to the laws of the unconscious and his conduct is not to be judged by them but by its harmony with a real and external not-self that man has built up through the ages.

The instincts of the herd in peace and war. By W. TROTTER. London, T. Fisher Unwin, 1916. 313 p.

This book is made up partly of essays written at various times since 1908 by a surgeon interested in psychological matters, and who writes a very effective style. It is a book that should be carefully read and pondered by every psychologist, for to this science it really makes valuable and new contributions. It is in a sense a little lacking in unity, the review of Freudianism and especially the war chapters having been rather an afterthought. At the same time, back of this the book really has a fundamental unity. The author goes far beyond the writers of the Tarde and LeBon school in insisting that the herd instinct is just as fundamental as those instincts generally classed as more primitive. He does not agree with Freud that the former are well developed and then repressed by social tendencies, but believes the latter to have been primordial and makes them the key to the explanation of some of the most fundamental things in life. Having developed his main thesis, he applies it to the issues of the war by urging that the Germans represent the wolf type and the English the sheep type of the herd instinct. Dr. John T. MacCurdy has written an excellent little ten-page summary of the work in the Psychiatric Bulletin for January, 1916, and has a high appreciation of the brilliant speculations of the author, who holds that psychology is the science of the future. One cannot but wonder whether a surgeon with such strong psychological proclivities may not, in what he says about the solution of the conflict between experience and herd suggestion, write with some personal warmth.

The psychology of the negro; an experimental study. By GEORGE OSCAR FERGUSON, JR. (Archives of Psychology, No. 36, April, 1916.) New York, Science Press. 138 p.

In his preliminary account of the non-experimental studies, the author does strange injustice to Odum's work, which is by far and away the best of all studies ever made in this field, compared with which the works of Tylor, Hall, Thorndike and the rest, are insignificant. Of course the author's work is experimental, but we maintain that he should have correlated in his own thought at least the very voluminous literature on the subject instead of practically having ignored it. It is by no means clear how much we can trust the maze, cancellation, sorting and other tests, and the author seems to have an exaggerated idea of the reliability of these methods. Certainly his own experiments afford him very few data for the "general comparison of whites and negroes" which he attempts. The author seems to the writer of this note bitten with the method fetichism that pervades the atmosphere in which he did his work.

How to live. By IRVING FISHER and EUGENE LYMAN FISK. New York, Funk and Wagnalls Co., 1916. 345 p.

This work is a rare combination of the scientific and practical. It is wrought out in collaboration with the Hygienic Board of the Life Extension Institute. It contains a brief but excellent foreword by

ex-President Taft, and an account of the above Board with photographs of its leading members. It covers such points as housing, clothing, outdoor life and sleeping, deep breathing, various themes connected with food and poisons, work, play, sleep, serenity, general hygiene, its rules, unity, obstacles, relations to civilization, etc., with eight supplementary notes on such topics as over-weight, under-weight, posture, alcohol, tobacco, avoiding colds, signs of disease, constipation and degenerative tendencies, and eugenics.

The mythology of all the races. Edited by LOUIS HERBERT GRAY. *Vol. I. Greek and Roman.* By WILLIAM SHERWOOD FOX. Boston, Marshall Jones Co., 1916. 354 p.

This opening volume of a series of thirteen which is contemplated, with its preface by Professor G. F. Moore of Harvard, makes an excellent impression in both the quality of work and the get-up of the book. It has long seemed to us that the need of some such thesaurus of mythology was great. If the series can be carried to completion on the same high grade as this initial volume it will be a godsend now that mythology is coming to have a new entire symbolic interpretation. We shall look with great interest to see what attitude the editors take with regard to the new psychoanalysis of myths.

La système Taylor et la physiologie du travail professionnel. By J. M. LAHY. Paris, Masson et Cie, 1916. 198 p.

This is an epitome of the efficiency work and ideas of the late Frederick W. Taylor which are set forth with lucidity in nine chapters. The author seems to share with little reservation Mr. Taylor's views of the economy of movement and professionalization of labor. In separate chapters he discusses salaries, efficiency in business organizations, the psychology of work and the problems of fatigue, and in the concluding chapter hails the work of Mr. Taylor as of very great significance.

The function of socialization in social evolution. By ERNEST W. BURGESS. Chicago, University of Chicago Press (c. 1916). 237 p.

This work is divided into three parts. The first treats of the rôle of socialization in discovery and invention, its relations to specialization, the social heritage, organization, stimuli and demand; the second treats of its rôle in social progress, from the kinship to the personal stage, including feudal, town and finally the impersonal stage of socialization. Part three treats of its rôle in personal development, its cognitive, affective and volitional aspect.

The British Journal of Psychology. Edited by CHARLES S. MYERS. Vol. 8, Part 2. May, 1916. Cambridge, University Press.

This number contains Part Three of N. Carey's Factors in the Mental Processes of School Children; this deals with the school subjects. It also contains an interesting article by James Ward on Sensory Character of Black.

Proceedings of the Royal Society of Medicine. Vol. 9, No. 7. May 1916. London, Longmans, Green and Co.

Medical Review of Reviews. Vol. 22, No. 7. July, 1916. Edited by VICTOR ROBINSON.

INDEX OF SUBJECTS

(The subject headings of all contributions except Book Reviews and Notes are printed in SMALL CAPITALS.)

Advertising, Laboratory test in, 285
AFFIRMATION, GESTURE OF, 320
AFTER-IMAGES, CUTANEOUS, 566; POSITIVE, 324
Alcohol, Psychological effects of, 291, 574
Apes, Mental life of, 440
ARTIFICIAL DAYLIGHT, USES IN THE PSYCHOLOGICAL LABORATORY, 427
ASSOCIATION METHOD, 119
ATTENTION, MEASUREMENT OF, 443; AND VISUAL IMAGERY, 461
Attitude, 294

Blood, Circulation of, 292
Bodily changes in emotions, 152

Character and temperament, 153
Children, Nervous, 441
CLOTHES, SIGNIFICANCE OF, 217
College, 292
COLOR PREFERENCE, 251
COMPENSATION OF ODORS, 435
COMPLEXITY OF COLOR HUES, SIMPLICITY VS., 273
Concentration, 290
Crowd, 292
Cube test, 284
CUTANEOUS, AFTER-IMAGES, 566; DETERMINATION OF LIMEN, 417; PERCEPTIVE FORMS, 569; SENSATION, 443

Defectives, 154, 283, 284, 294
Delinquents, Point Scale ratings of, 284
DEVELOPMENTAL PSYCHOLOGY IN LOWER ANIMALS AND MAN, 71
Dishonesty, Causes and treatment of, 292
Distraction, Overcoming of, 294
DOUBLE INVERSION, 203
DURATION AND THE TEMPORAL JUDGMENT, 1

ECONOMICAL LEARNING, 507
Education, 441; of defectives, 294; Social taboo in, 154
Efficiency, 579
Emotions, 152
Eugenics, 293
Evolution and the war, 577

Fantasy, and thought, 440
Fatigue, 441
FEELING, TRIDIMENSIONAL THEORY OF, 157
FRENCH THOUGHT ON THE EVE OF THE WAR, 297
FUNCTION IN BIOLOGY, STRUCURE AND, 245

GENIUS, PSYCHOANALYTIC STUDIES OF, 363
GESTURE OF AFFIRMATION AMONG THE ARABS, 320

Habit formation, Age and, 291
Hygiene, 153, 578

Immigrant, 155
IMPROVABILITY, 550
IMAGERY, VISUAL, 461
INITIAL SPURT IN A SIMPLE MENTAL FUNCTION, 256
Insanity, 291
INSTINCTS, TESTING THE STRENGTH OF, 227
Intellectual status of public charges, 293
INTROSPECTION, 572
INVERSION, MARKED CASE OF DOUBLE, 203

Knowledge, 152; Theory of, 287
Knox's cube test, 284
Külpe, Oswald, 296

LABORATORY EQUIPMENT, 530
Language, 291; scales, 294
LEARNING, 507; Quickness of, 293; with intention to retain, 420

LIFTED WEIGHT EXPERIMENTS, EFFECTS OF PRACTICE IN, 261
LOCALIZATION OF RECOGNITIONS, 341
LOWER ANIMALS, 71

MEASUREMENT OF ATTENTION, 443
MEMORY, 493
MENTAL TESTS, 71, 283, 284
Monkeys, Mental life of, 440
Motives, 287
Mythology, 579

Natural history of the state, 153
Negro, Psychology of, 578
Neurology, 152
Nietzsche's moral aim, 155
NORMAL COMPLEXES, CORRELATION OF, 119

Object, Subject and, 155
ODORS, COMPENSATION OF, 435
Organic individuality, 292

PERCEPTIVE FORMS BELOW THE LEVEL OF THE TWO-POINT LIMEN, 569
PHOTOMETER, DAYLIGHT, 335
Photoplay, 440
Plethysmograph sleeves, 295
Point Scale, 283, 284
Polyglottism, 291
PRACTICE, EFFECTS OF INITIAL, 261; IMPROVABILITY AND CURVE OF WORK, 550
PRIMITIVE NOTIONS OF THE "SELF," 171
PROPER NAMES, PSYCHOLOGICAL RESPONSE TO UNKNOWN. 430
Psychiatry, 286
Psychical research, 286
PSYCHOANALYTIC STUDIES OF GENIUS, 363
Psychobiology, 437
PSYCHOPHYSICS, 315, 417
PSYCHOMOTOR MECHANISMS OF TYPEWRITING, 47

Quickness of learning, Relation to retentiveness, 293

Rat, Age and habit formation in, 291
Realistic psychology, 154
Reason, 155
RECALL, RECONSTRUCTIVE, 493
Recognition, 154, 341
RECONSTRUCTIVE RECALL, 493
Relaxation, 290
Religion, 154
Retentiveness, Quickness of learning and, 293
Rhythm, 293

School hygiene, 153
School and immigrant, 155
"SELF," PRIMITIVE NOTIONS OF THE, 171
SENSATION, CUTANEOUS, 443
SIMPLICITY VS. COMPLEXITY OF COLOR HUES, 273
Sleep and sleeplessness, 288
Socialization, 579
Social status and mental tests, 283
Social taboo, 154
Sociology, 290
SPURT IN A SIMPLE MENTAL FUNCTION, INITIAL, 256
STRUCTURE AND FUNCTION IN BIOLOGY, 245
Subject and object, 155

Taboo, 154
Temperament, Character and, 153
TEMPORAL JUDGMENT, DURATION AND THE, 1
Tests, 441; OF STRENGTH OF INSTINCTS, 227; Standardization of, 283; for defective children, 283, 284; Cancellation, 293; Language, 294
Text-books on psychology, 155, 290, 292
Theory of knowledge, 287
Thought and fantasy, 440
Transfer effects, 293
TYPEWRITING, PSYCHOMOTOR MECHANISMS OF, 47
TRIDIMENSIONAL THEORY OF FEELING, 157

Unemployment, 153

VARIABILITY, MEASURES OF, 234
VISUAL IMAGE, AROUSAL OF PRIMARY, 87; AND ATTENTION, 461

War, 441, 577, 578; FRENCH THOUGHT ON EVE OF, 297
WORK, CURVE OF, 550

Yoga-system of concentration, 290

INDEX OF AUTHORS

(The names of authors of original contributions are printed in SMALL CAPITALS.)

ABBOT, E. STANLEY 245
Adams, H. F. 285
ALSPACH, E. M. 273
Anderson, Helen M. 283
ARPS, GEORGE F. 203, 507
v. Aster, E. 292

Barton, Wilfred M. 441
Benedict, Francis G. 291
Bigham, J. A. 442
BLISS, SYLVIA H. 217
BODE, B. H. 287
Bonaventura, Enzo 295
BORING, E. G. 315
BOSWELL, F. P. 420
BRADFORD, E. J. G. 234
BROWN, A. J. 427
Brown, Charles R. 442
Bruce, H. Addington 288
Burgerstein, Leo 153
Burgess, Ernest W. 579
BURTT, HAROLD E. 87

Cannon, Walter B. 152
CARNES, M. 417
CHAPMAN, J. CROSBY 256
Child, Charles Manning 292
CLARK, HELEN 461
CONARD, H. E. 507
Conway, Martin 292
de Coubertin, Pierre 156
Crawford, William H. 292
Curtis, John G. 292
CURTIS, JOSEPHINE NASH 1

DALLENBACH, K. M. 443
DIMMICK, F. L. 566
Dodge, Raymond 291
DOOLEY, LUCILE 119, 363
Dowd, Jerome 156
Dunlap, Knight 156, 295, 437

ENGLISH, G. 430
Epstein, Izhac 291

Ferguson, George Oscar, Jr. 578
FERNBERGER, SAMUEL W. 261, 295
FERREE, C. E. 335
Fisher, Irving 578
Fisk, Eugene Lyman 578
Ford, Henry Jones 153
FOSTER, W. S. 157, 420
Fox, William Sherwood 579
Freeman, Frank Nugent 441
Fröbes, Joseph 155
Fuller, Justin K. 442

GEORGE, S. S. 320
Gilbreth, Frank B. 441
Gilbreth, Lillian M. 441
Givler, Robert Chenault 154
Goldsmith, Peter H. 295
Gould, Benjamin Apthorp 441
Gray, Louis Herbert 579
Green, J. A. 155
Guyer, Michael F. 293

Haines, Thomas H. 284
Hayes, Joseph Wanton 156
Healy, William 292
Herrick, C. Judson 152
Holmes, Arthur 154
Hubbert, Helen B. 291
Hume, David 156

Ingram, Robert 442

Janet, Pierre 574
Jastrow, Joseph 153
Jones, Edith Kathleen 294
Jordan, Alfred C. 155

Kellor, Frances A. 153
Kirkpatrick, Edwin A. 295

Ladd, George Trumbull 154
Lahy, J. M. 579
Larson, Christian D. 294, 442
DE LASKI, E. 569
LUCKIESH, M. 251
Lyon, Darwin Oliver 293

Macintosh, Douglas Clyde 152
Marden, Orison Swett 294, 441
Martin, Melvin Albert 293
Mitchell, P. Chalmers 577

INDEX OF AUTHORS

Moore, Henry T. 227
Morgan, John J. B. 294
Müller-Freienfels, Richard 440
Münsterberg, Hugo 440
Myers, Caroline E. 493
Myers, Garry C. 493

Nolan, Willis J. 256

Ordahl, George 442
Ordahl, Louise Ellison 442
Orton, S. T. 437
Owen, Roberts Bishop 154

Patrick, George Thomas White 290
Patterson, Charles Brodie 293
Peters, Iva L. 154
Philip, Alexander 287
Pintner, R. 284
Polak, S 155
Putnam, James Jackson 287

Quilter, H. C. 155

Rand, Gertrude 335
Rebizzi, Renato 442
Roese, K. 157
Ruckmich, Christian A. 287, 288, 530

Salmon, Alberto 294, 442
Salter, William Mackintire 155
de Sanctis, Sante 294
Schinz, Albert 297
Schmitt, Clara 283
Shearer, L. C. 417
Sheppard, Edmund E. 155
Shiels, Albert 155
Sioli, F. 286
Smith, Frederick M. 574
Smith, Stephen 291
Stenquist, J. L. 293
Stepanow, Giovanni 442
Stevenson, Beatrice L. 153
Strong, Edward K., Jr. 341
Strong, Margaret Hart 341
Swift, Walter B. 71
Swindle, P. F. 324

Tanner, Amy E. 286
Taylor, A. E. 156
Terman, Lewis M. 442
Thorndike, Edward L. 293, 550
Titchener, Edward Bradford 273, 290, 417, 435, 566, 569
Todd, Arthur J. 171
Trabue, Marion Rex 293, 294
Trotter, W. 578
Tucker, Beverley R. 441

Von der Osten, Anna L. 153

Wallis, W. D. 572
Walter, Johnston Estep 155
Weld, H. P. 273, 417, 566, 569
Wells, Frederic Lyman 47, 291, 294
Williams, Tom A. 156
Woods, James Haughton 290

Yerkes, Robert M. 283, 440, 442
Yost, Casper S. 294